9-11

4100.01

United States Department of the Interior

BUREAU OF RECLAMATION
Boulder Canyon Operations Office
P.O. Box 61470
Boulder City, NV 89006-1470

IN REPLY REFER TO:

BCOO-4640
RES-1.10(CAL)

FEB 5 1998

Mr. Fawzi Karajeh, Program Manager
Agricultural Drainage Reduction
Office of Water Conservation
California Department of Water Resources
1020 Ninth Street, 3rd Floor
Sacramento CA 95814

Subject: Runoff Reduction Demonstration Project

Dear Mr. Karajeh:

To this point we are very pleased with the progress of the current runoff reduction demonstration project by Dr. Khaled Bali. However, It was noted by Steve Knell in his December 29, 1997, letter that the objectives of the project have not yet been achieved. It is understood that the first 2 years of this project were to concentrate on data collection, and we still expect that in the coming year the remaining objectives will be accomplished.

As all the objectives of this project are completed, we believe we will have a better understanding as to the value of further research on commercial fields in the proposed format. At this time we will decline to participate as proposed. We question the value of expanding this project to commercial fields in the same format as the original project.

However, we are interested in discussing a different approach. We would be interested in participating in a demonstration and extension program that would take the cutoff time technique and apply it throughout the Imperial Valley with cooperating growers. This could be similar to the mobile lab programs where irrigation evaluations could be made on each farm comparing the existing method and the new method. Research involved could be limited to refining and applying the cutoff time technique to different soils and irrigation systems. We believe that such a program would be much more valuable than an intensive look at a few fields.

If you have any questions, please call me at 702-293-8186.

Sincerely,

Stephen M. Jones
Regional Water Conservation Coordinator

cc: Dr. Khaled Bali
Associate Cooperative Extension Advisor
University of California, Imperial County
1050 E. Holton Road
Holtville CA 92250-9615

Mr. Steve Knell, Superintendent
General, Drainage Section
Imperial Irrigation District
P.O. Box 937
Imperial CA 92251

Area Manager, Yuma AZ
Attention: YAO-6200

9-12

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United States Department of the Interior

BUREAU OF RECLAMATION
Boulder Canyon Operations Office
P.O. Box 61470
Boulder City, NV 89006-1470

IN REPLY REFER TO:

BCOO-4640
RES-1.10(CAL)

FEB 4 1998

Dr. Khaled Bali
Associate Cooperative Extension Advisor
University of California, Imperial County
1050 E. Holton Road
Holtville CA 92250-9615

Subject: Discussion Paper by Bali and Grismer

Dear Mr. Bali:

Thank you for the opportunity to evaluate and provide comments on the fourth draft of the Runoff Reduction Project. The major focus of the project is whether improved border irrigation management can significantly reduce surface runoff, and yet result in relatively good yield distribution. Much of the data dealt with yield and salinity distribution along the border. The results indicated that on alluvial clay soils, good yields and salinity management can be achieved with very little runoff with good control of the volume inflow to each border strip.

We were particularly interested in the yield and estimated evapotranspiration (ET) for alfalfa and Sudan grass in the Imperial Valley. The cumulative alfalfa yield and associated from January 22-23 to December 20 was about 48.1 inches, and the yield was 8.03 tons/acre. This is essentially 6.0 inches per ton. The cumulative ET for Sudan grass was 39.6 inches and 37.3 inches in 1996 and 1997, respectively. The associated yields were 6.84 tons/acre in 1996 (three cuttings) and 5.43 tons/acre in 1997 (two cuttings). We encourage you to put the detailed water and yield data in an appendix and summarize the results on an annual or seasonal basis for comparison with other published data.

Your real-world demonstration of a relatively simple way to estimate cutoff time, to reduce runoff, has great value by providing farmers another tool to implement on farm water management decisions. More emphasis should be put on and application of this technique in the Imperial Valley. We would like to see more evidence of progress in this area, but trust it will be forthcoming.

If you have any questions, please call me at 702-293-8186.

Sincerely,

Stephen M. Jones
Regional Water Conservation Coordinator

cc: Mr. Steve Knell
Superintendent
General, Drainage Section
Imperial Irrigation District
P.O. Box 937
Imperial CA 92251

Mr. Fawzi Karajeh
Program Manager,
Agricultural Drainage Reduction
Office of Water Conservation
California Department of Water Resources
1020 Ninth Street, 3rd Floor
Sacramento CA 95814

Area Manager, Yuma AZ
Attention: YAO-6200

9-13

400.01

(760) 339-9826
FAX (760) 339-9895

WD

January 5, 1998

DS SRK

Fawzi Karajeh
Program Manager, Agricultural Drainage Reduction
Office of Water Conservation
California Department of Water Resources
1020 Ninth Street, 3rd Floor
Sacramento, Ca. 95814

Dear Mr. Karajeh,

Subject: On-Farm Irrigation Management and Surface Runoff Reduction Project

At the present time, the Imperial Irrigation District will not be able to participate in the On-Farm Irrigation Management and Surface Runoff Reduction Project submitted by Dr. Khaled Bali in a November 7, 1997 letter. Dr. Bali submitted this proposal at the request of our Water Conservation Advisory Board to address field testing at the farm level of his current work. The principal reason is that the project has come too late in our budget process to be funded in 1998. As a result of a recent water rate increase to balance our 1998 budget, it is doubtful our Board will move forward and approve such an expense at this time.

Steve Knell of our staff has talked with Steve Jones, Bureau of Reclamation, concerning this matter and Mr. Jones was going to contact you and discuss the Bureau's final decision. We will however continue to monitor and participate in the progress of the current Irrigation and Drainage Management and Surface Runoff Reduction project at the Meloland Station. The results and outcome of this project will most decidedly determine our involvement in 1999.

Sincerely,

Eldon L. Moore

ELDON L. MOORE,
Assistant General Manager-Water

Copy to: Steve Jones, Bureau of Reclamation

SRK:br

9-14

4/30,01

(760) 339-9326
FAX (760) 339-9895

WD

December 29, 1997

Khaled Bali
Associate Cooperative Extension Advisor
University of California, Imperial County
1050 E. Holton Road
Holtville, CA 92250-9615

Dear Mr. Bali,

Subject: Comments to Draft Progress Report-Runoff Reduction Project

Thank you for the opportunity to evaluate and provide comments on the fourth draft report of the Runoff Reduction (Research) Project. I have been asked to assume Tim O'Halloran's liaison responsibilities for the Imperial Irrigation District (IID) as they relate to this research project and to interact with the other committee members, Fawzi Karajeh of the Department of Water Resources and Steve Jones with the Bureau of Reclamation.

My only exposure to the research project thus far has been the presentation made December 4, 1997 to a select group of participants and in reading your recently released draft of the fourth progress report. I am a fanatic for formalized responses to work or actions that affect the Imperial Irrigation District. This comes from years of dealing in the environmental arena on pesticides and pollutants in agricultural drain water. I have found that formalized (written) responses lead to substantive discussions in that we can work from a position of understanding.

I believe the premise of your research work has great value and that the results can provide farmers with another "tool" to implement on farm management decisions. However, for a tool to be useful it must be functional and, more importantly, it must be a good tool. Being a good tool means it has stood the scrutiny of its developers *and* its end users. I consider the committee members of DWR, BOR, IID and yourself as the developers of this tool. I would like to think that at the conclusion of this research project that all the participants (developers) are comfortable with the results and that in fact we have developed a good tool. A tool worthy of the second step of tool development, that is, end user testing. With that in mind, I offer the following constructive comments to your draft report.

To familiarize myself with the intent of your work I read through the contract documents the three agencies (BOR, DWR and IID) signed with the University Regents for this study. In comparing your draft report and the Objectives listed in the contract, I found insufficient detail in the draft report to conclude that satisfactory accomplishments are being made towards achieving the study Objectives. The following is a list of the 9 objectives from the contract and my comments on the deficiencies I see in the draft report:

Objective 1. improve irrigation efficiency,
Comment: Nowhere in the draft report is the reader lead to the conclusion that irrigation efficiencies are improving. Applied water is tabulated in the draft report but soil moisture deficits at the time of irrigation, runoff volumes and deep percolation losses are missing. For most of us, this is valuable information and should be presented in the report in an understandable format.

Objective 2. reduce surface runoff,
Comment: There is somewhat of a presumptuous statement in the Introduction that, ". . . a significant amount of water was saved as a result of reduced surface runoff and one-irrigation per cutting treatment.", but again, nowhere in the draft report is the data to substantiate that claim.

In addition, it is my opinion that this type of statement is better reserved for the conclusion of the study, after *all* the water data has been documented. This statement lacks the recognition that an unknown quantity of reclamation (leaching) water will be needed to return the soil profile to its pre-study EC levels. I think it would be helpful to qualify any and all results in the future as tentative pending the studies final outcome

Objective 3. determine the contribution of shallow saline water tables to crop evapotranspiration in heavy clay soils,
Comment: Water table elevations are given in a table and plotted in a time-graph but this data does little to answer the question posed by Objective 3. In your verbal presentation you state that 20% of the crops ET is coming from the water table. The basis for that conclusion is what?

Objective 4. determine the effect of water table control on irrigation management and consumptive use of water by alfalfa and sudangrass (including crop coefficients for alfalfa and sudangrass),
Comment: The draft report does not show any data or information being gathered about crop coefficients for alfalfa and/or sudan. This was a principal reason IID became interested in this study was for the development of ET data.

Objective 5. develop a relatively simple approach to predict irrigation cutoff time from predetermined soil moisture measurements,
Comment: Again, the draft report omits any statements about the development of cutoff time determination.

Objective 6. increase the utilization of CIMIS for irrigation scheduling,
Comments: The draft report lacks any information about CIMIS, and specifically, what ET data is being gathered or how it is being used to schedule irrigations in this study. Are irrigations being done off ET from CIMIS or by neutron probe data? Even more importantly, how does the CIMIS ET data compare with what the neutron probe data is showing.

Objective 7. develop a user-friendly computer program and irrigation management spreadsheets for efficient irrigation management practices,
Comment: The draft report has a printout of a computer program but this alone does not indicate if it is user friendly or not. Does the computer program in the draft report yield irrigation management spreadsheets that can be used for efficient irrigation management practices? A printout would be helpful.

Objective 8. publish a handbook about the best management practices for reducing surface and subsurface drainage water, and
Comment: How far along is this handbook?

Objective 9. conduct field days, demonstrations, seminars, and publish results in both popular and scientific media.
Comment: To a limited audience this is being done. However, without the supportive data being available in Objectives 1-8 above to substantiate this work, I question the value of the meetings to the participants.

From your verbal presentation it is obvious that the information is available, however it is not being presented in sufficient written detail to indicate that accomplishments are being made towards satisfying the contract objectives. What I would like to see in your current and future draft progress reports are a section on each one of these objectives. Included in each section would be a presentation of the data gathered towards accomplishment of the contract objective, written text disseminating the data and any qualified statements the researcher may have. The information should be presented thoroughly, concisely and with enough detail that the reader does not have to interpret what the researcher did to arrive at his conclusions or thoughts.

The following are personal comments related to the study that do not fit in the above discussions:

- I would like to see a section in future reports outlining in detail the elements that make this a research project (i.e., that irrigations are done out of a reservoir and not subject to normal canal fluctuations, that irrigations are conducted in daylight hours only and not subject to night time errors, that more than one irrigator is present at all times to measure and correct inflow water rates, that irrigations have the ability to be terminated at any time, without notice of shut off, compared to 12 and 24 hour set restrictions of IID's system, and . . . whatever other qualifying statements that may need to be made such that the casual reader understands that this is a research project and not real life.)

- Another issue is the "standard field with irrigation runoff". I assume this is the "control field", the one upon which comparisons are made. We should follow normal practice and subscribe as much value and weight to the information gathered off the *control field* as the *test field*.

- I find it curious that the EC in the sudan field is actually dropping during the course of the study. If this is the case, I can see why no yield reduction occurred. I'm surprised that this is occurring while deficit irrigations are being applied. Is there an explanation for this?

- With the EC of the groundwater being reported in the 19-20 mmhos range at the 48-inch depth, this would equate to a reduction in the available water holding capacity at that depth of 60%. Isn't the osmotic ability of the plant to extract moisture at that level severely impaired? I hope the supportive research can provide an explanation for this phenomena.

- The consistent and severe dip in the EC values recorded at 350-500 feet down the border interests me. This dip also shows up in the Cl samples taken. My field experience says that a low spot may occur in this area adding to slightly more water entering the soil profile at that location. Your advance/recession data may show this to be true or not. Even more curious is the yield data along the same border. This data shows an increase in yield around that same area. More water, more yield, makes sense.

Again, please accept what I've presented as constructive input with the intent of providing the best usable tool for our decision makers, the growers. I'm available to meet with you and/or the committee at your convenience and discuss any and all the information presented here. My office number is (760) 339-9826.

Sincerely,

STEVE R. KNELL, P.E.
Superintendent, General,
Drainage Section

Copy to: Fawzi Karajeh, Department of Water Resources
Steve Jones, Bureau of Reclamation

SRK:br
(UCSALI1.LTR)

9-15

COOPERATIVE EXTENSION
UNIVERSITY OF CALIFORNIA
IMPERIAL COUNTY

1050 E. HOLTON ROAD
HOLTVILLE, CA 92250-9615

TELEPHONE
(619) 352-9474

FAX NUMBER
(619) 352-0846

December 3, 1997

Fawzi Karajeh - DWR Fax (916) 327-1815 (1828) Phone #
Eldon Moore -IID Fax (760) 339-9262
Steve Jones -USBR Fax (702) 293-8042

Re: Draft Progress Report- Runoff Reduction Project

Attached please find a draft of our ~~four~~ progress report for the above project. If you have any comments or suggestions about the attached report, please forward them to me by fax (760-352-0846) or email (kmbali@ucdavis.edu) no later than February 1, 1998.

Thank you for your time and consideration.

Sincerely,

Khaled M. Bali
Associate Cooperative Extension advisor
Irrigation/Water Management

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DRAFT FOR DISCUSSION ONLY

Data presented in this report are preliminary *and not for publication* until authorized by the investigators

FOURTH PROGRESS REPORT DUE 12/31/97

Irrigation and Drainage Management and Surface Runoff Reduction in Imperial Valley

Principal Investigators: Khaled M. Bali, Ph.D.
Farm Advisor, Irrigation/Water Management
University of California Cooperative Extension
UC Desert Research and Extension Center
1050 E. Holton Rd., Holtville, CA 95616-9615
(760) 352-9474 Fax: (760) 352-0846 E-mail: kmbali@ucdavis.edu

Mark E. Grismer, Ph.D.
Professor, Hydrologic Science, Veihmeyer Hall
Land, Air and Water Resources
University of California, Davis, CA 95616
(916) 752-3243 Fax: (916) 752-5262 E-mail: megrismer@ucdavis.edu

Cooperators: Richard L. Snyder, Ph.D.
Bioclimatologist, Atmospheric Science, Hoagland Hall
University of California, Davis, CA 95616
(916) 752-4628 Fax: (916) 752-1552

DRAFT FOR DISCUSSION ONLY 2

Data presented in this report are preliminary *and not for publication* until authorized by the investigators

1 Introduction:

Colorado River water is the only source of irrigation and drinking water in the Imperial Valley. About 2.8-3.0 million acre-feet of water are used every year to irrigate more than 500,000 acres of lands in the Imperial Valley. Approximately 17% of the delivered irrigation water in the Imperial Valley becomes tailwater runoff. All surface and subsurface drainage water enters the Salton Sea which has been serving as a drainage sink for the Imperial and Coachella Valleys since its formation in 1905. The Salton Sea continues to exist because of the drainage water from agriculture in Imperial and Coachella Valleys as well as flow of agricultural drainage and untreated and partially treated sewage from the Mexicali Valley. Because of drainage and its impact on the Sea, several water quality issues exist in the Imperial Valley for which water conservation plays a role.

The objective of the current project is to conduct a research and demonstration program that will improve irrigation efficiency, reduce surface runoff, utilize the shallow saline water table for new and improved irrigation and drainage management practices, determine crop coefficients for two common field crops (alfalfa and sudangrass) and increase utilization of CIMIS for irrigation scheduling. The focus of the current project is on the development and demonstration of a new method to predict irrigation cutoff time from pre-determined soil moisture status of the clay soil of interest. Issues related to salinity, irrigation management, and water quality will also be addressed in this project. Since soil salinity and water management are affected by water table depth, a major part of this study will be to quantify the effect of water table control on soil salinity, water infiltration rates, and irrigation efficiency. To observe cumulative effects of water table on soil salinity and consumptive water use, this study is conducted for three years (1995-1998). Early results from this research and demonstration project show a reduction in alfalfa yield in the second year as a result of a combination of surface runoff reduction and one-irrigation per cutting irrigation treatment. However, a significant amount of water was saved as a result of reduced surface runoff and one-irrigation per cutting treatment. Sudangrass yield was not affected as a result of the surface runoff reduction treatment which resulted in significant water savings.

The main focus of this study is to develop and demonstrate the use of a volume balance method to predict irrigation cutoff time to reduce surface runoff to approximately 5% or less of the applied water. Issues related to salinity, hay yield and quality, and water quality will be addressed in this project. The focus of this work is on field crops, specifically alfalfa and sudangrass. Field crops account for almost 80% of the 500,000 acres of irrigated land in the Imperial Valley and alfalfa and sudangrass rank first and third, respectively, in terms of harvested acreage of field crops (1996 Imperial County Agricultural Crop and Livestock report). These two major field crops were grown on more than 244,000 acres of irrigated lands in the Imperial Valley in 1996.

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Data presented in this report are preliminary *and not for publication* until authorized by the investigators

2 Objectives:

1.86 acres/border *4 = 7.46 Acres

Summary:

Alluvial clay soil at the University of California Desert Research and Extension Center, Holtville, CA, was cultivated and alfalfa seeds were planted in November 1995 (Field No. 2). Sudangrass was planted in April 1996 and April 1997 (Field No. 1). A total of 15 acres are used in this project. The area is divided into 2 fields each containing separate plantings of alfalfa and sudangrass. Each field contains 4 borders where each border is 65 ft*1250 ft. Thirty two sampling locations were established in each field to evaluate soil moisture and soil salinity at 14 different depths (6 inches to 9 ft). Moisture contents at all sampling locations were determined by the neutron probe. The neutron probe was calibrated for each field. Soil moisture measurements were made prior to each irrigation and 2 or 3 days after each irrigation. Alfalfa and sudangrass hay samples were taken for yield determination. Summary of alfalfa and sudangrass data are presented in the progress report. **Data presented in this report are preliminary and not for publication until authorized by the investigators.**

Field No. 1, Crop: Sudangrass

1996 Season: Planting rates and dates: Sudangrass (cv. 'Piper') was planted on April 15, 1996 at the rate of 120 pounds of seed per acre.

1996 season

Irrigation Date	Average Depth of Application in inches (based on Q measurements) or? Are these ac-inches/Acre or ~~ac-inches/4 borders~~
1-18-96 (preirrigation)	3.87
4-16-96	3.95
5-3-96	2.84
5-24-96	5.08
6-28-96	6.92
7-23-96	5.72

What was SMD at time of irrigation?

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Data presented in this report are preliminary *and not for publication* until authorized by the investigators

8-20-96	6.94
9-17-96	6.05
Total	39.6 (3.30 ac-ft/ac)

Sudangrass was cut on:

Cut date	Average yield (tons/acre) field wt.	Average yield (tons/acre) adjusted to 10% moisture
6-17--96	2.38	2.37
8-7-96	2.25	2.24
10-10-96	2.13	2.23
Total 1996	6.76	6.84

Soil samples between 3-29-96 and 11-25-96

1997 season

1997 Season: Planting rates and dates: Sudangrass (cv. 'Piper') was planted on April 18, 1997 at the rate of 120 pounds of seed per acre.

Pest control and harvesting: According to the commercial practices of sudangrass production in Imperial Valley.

Irrigation Date	Average Depth of Application in inches (based on Q measurements)
4-21-97	5.69
5-5-97	1.73
6-2-97	7.42
6-20-97	5.35
7-9-97	5.70
7-29-97	5.18

Data presented in this report are preliminary *and not for publication* until authorized by the investigators

8-20-97	6.04
9-10-97	5.47
10-10-97	3.63
Total	46.48 (3.87 ac-ft/ac)

Sudangrass was cut on:

Cut date	Average yield (tons/acre) field wt.	Average yield (tons/acre) adjusted to 10% moisture
7-1-97	3.07	2.99
10-3-97	2.36	2.32
Total 1997		

Soil samples between November 1996 and November 1997

Field No. 2, Crop: Alfalfa

Alfalfa (CUF 101) was planted on November 7, 1995 at a rate of 30 pounds of seed per acre.

Pest control and harvesting: According to the commercial practices of alfalfa production in Imperial Valley.

IrrigationDate(s)	Average Depth of Application in inches (based on Q measurements)
11-8-95	3.91
12-4 & 12-5-95	3.53
1-22 & 1-23-96	5.01
3-19-96	5.52
4-24-96	6.13

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5-17-96	5.62
6-7-96	4.99
7-3-96	5.57
8-2-96	5.49
9-10-96	5.28
11-1-96	5.30
12-20-96	4.19
2-19-97	4.37
4-7-97	4.65
4-28-97	4.66
5-19-97	4.57
6-16-97	4.56
7-11-97	5.27
7-23-97	1.42 (only two lands were irrigated)
8-8-97	4.80
8-19-97	1.79 (only two lands were irrigated)
9-5-97	4.88
10-18-97	4.60
Total to date (11/1/97)	106.11 (8.84 ac-ft/ac)

1½ year ??

Soil samples between 11-3-95 and October 1997

Alfalfa was cut on:

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Data presented in this report are preliminary *and not for publication* until authorized by the investigators

Cut date	Average yield (tons/acre) field wt.	Average yield (tons/acre) adjusted to 10% moisture
3-6-96	0.96	0.88
4-17-96	0.91	0.87
5-30-96	1.49	1.40
6-24-96	1.97	1.91
7-24-96	1.08	1.08
8-28-96	0.88	0.77
10-21-96	0.58	0.57
12-11-96	0.55	0.55
2-4-97	0.63	0.58
3-27-97*	**	**
5-8-97	1.35	1.30
6-6-97	1.06	1.03
7-7-97	0.74	0.73
8-1-97	0.82	0.80
8-29-97	0.78	0.75
10-10-97	0.30	0.29
Total (11/1/97)	14.10	13.51

* to control insect damage (aphid and weevil), field sprayed on 4/4/97

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Alfalfa yields (alfalfa yield next to each of the 32 sampling locations, sample area is 0.91 m*6.10 m) on:

Cut date	Average yield (Kg/ha) dry matter	Average yield (tons/acre) dry matter
3-4-96	2768	1.23
4-17-96	2801	1.25
5-28-96	3822	1.70
6-24-96	3971	1.77
7-24-96	2896	1.29
8-27-96	1947	0.87
10-15-96	1845	0.82
12-9-96	1402	0.62
2-4-97	1321	0.59
3-27-97	**	**
5-7-97	2691	1.20
6-5-97	2669	1.19
7-7-97	2054	0.92
8-1-97	2126	0.95
8-29-97	1935	0.86
10-7-97	1353	0.60
Total (up to 11/1/97)	35,601	15.86

Fields 1 and 2

Colorado River water was applied to all fields. We evaluated the irrigation efficiency of each field

Can we see?

would like to see

Adjusted value?

and for each irrigation by taking advance, recession, and flow rate measurements for all borders. Infiltration rates were evaluated for each irrigation using the advance function. A total of 32 9-ft neutron probe access tubes were installed in each field (eight neutron probe access tubes were installed in each border) to characterize soil moisture distribution in the field. Moisture measurements were taken at depths of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0, 7.0, 8.0, and 9.0 ft prior to and two or three days following each irrigation. Gravimetric soil moisture samples were taken in the 0-6" depth range because the neutron scattering technique does not accurately estimate soil moisture content near the surface. Evapotranspiration during and for the two or three days following irrigations were obtained from CIMIS weather station No. 87 and were added to the difference in soil moisture prior to and following each irrigation. A total of 32 10-ft observation wells were installed in each field. Water samples from each well were taken for salinity and Cl analysis of the shallow groundwater. Soil samples from the 32 locations in each field were taken at various depths to evaluate soil salinity.

What is this data

DRAFT

File: a80owlf AREA 80 Alfalfa

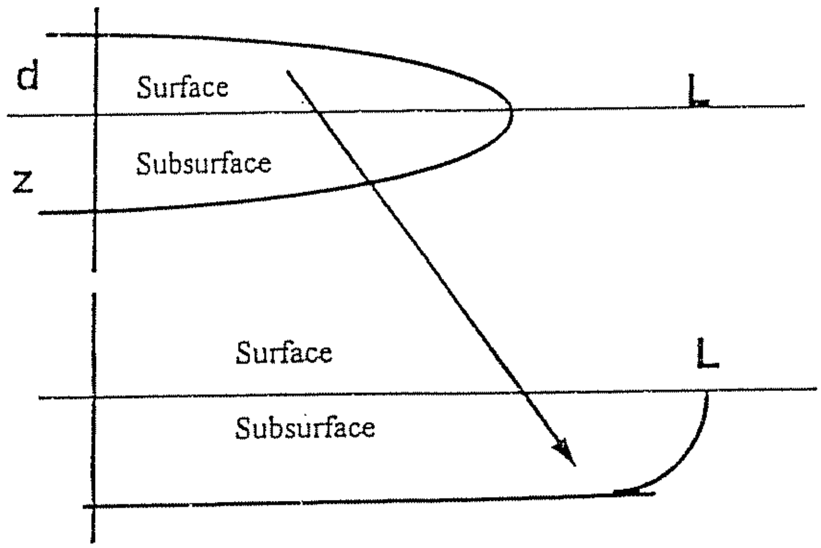
Observation well levels before/after irrigations

Lands 1-4

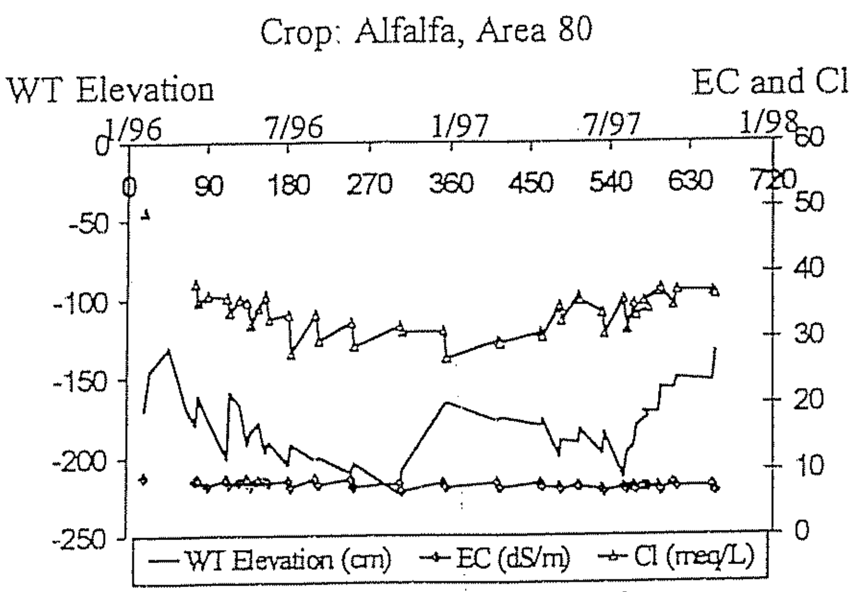
Each value represents the average of 32 locations

Date	Cum. date (1/1/96)	Avg. Level (in)	cm below GL	Lands 1-4
01/19/96	19	66.688	-169.4	Before Irrigation
1/25/96	25	57.141	-145.1	After Irrigation
2/15/96	46	51.313	-130.3	Before Irrigation
3/7/96	66	66.219	-168.2	Before Irrigation
3/18/96	77	70.609	-179.3	Before Irrigation
3/21/96	80	63.422	-161.1	After Irrigation
4/1/96	91	69.125	-175.6	Before Irrigation
4/23/96	113	78.984	-200.6	Before Irrigation
4/26/96	116	62.516	-158.8	After Irrigation
5/7/96	127	65.578	-166.6	Before Irrigation
5/16/96	136	75.266	-191.2	Before Irrigation
5/20/96	140	72.234	-183.5	After Irrigation
5/29/96	149	70	-177.8	Before Irrigation
6/6/96	157	77.234	-196.2	Before Irrigation
6/10/96	161	74.781	-189.9	After Irrigation
7/2/96	183	80.359	-204.1	Before Irrigation
7/5/96	186	75.375	-191.5	After Irrigation
8/1/96	213	79.453	-201.8	Before Irrigation
8/5/96	217	78.641	-199.7	After Irrigation
9/9/96	252	82.625	-209.9	Before Irrigation
9/12/96	255	80.125	-203.5	After Irrigation
10/31&11/1/96	305	87.771	-222.9	Before Irrigation
11/4/96	308	81.807	-207.8	After Irrigation
12/19/96	353	66.146	-168.0	Before Irrigation
12/23/96	357	65.359	-166.0	After Irrigation
2/18/97	414	69.786	-177.3	Before Irrigation
2/21/97	417	68.974	-175.2	After Irrigation
4/7/97	462	70.859	-180.0	Before Irrigation
4/9/97	464	69.453	-176.4	After Irrigation
4/28/97	483	78.661	-199.8	Before Irrigation
4/30/97	485	74.417	-189.0	After Irrigation
5/19/97	504	75.172	-190.9	Before Irrigation
5/21/97	506	71.813	-182.4	After Irrigation
6/16/97	532	77.745	-197.5	Before Irrigation
6/18/97	534	72.625	-184.5	After Irrigation
7/10/97	556	83.628	-212.4	Before Irrigation
7/14/97	560	77.521	-196.9	After Irrigation
7/22/97	568	75.813	-192.6	Before Irrigation
7/25/97	571	71.086	-180.6	After Irrigation
8/7/97	584	68.417	-173.8	Before Irrigation
8/11/97	579	67.422	-171.3	After Irrigation
8/18/97	595	67.653	-171.8	Before Irrigation
8/21/97	598	61.563	-156.4	After Irrigation
9/4/97	612	61.763	-156.9	Before Irrigation
9/8/97	616	59.188	-150.3	After Irrigation
10/17/97	655	59.859	-152.0	Before Irrigation
10/20/97	658	52.703	-133.9	After Irrigation

DRAFT

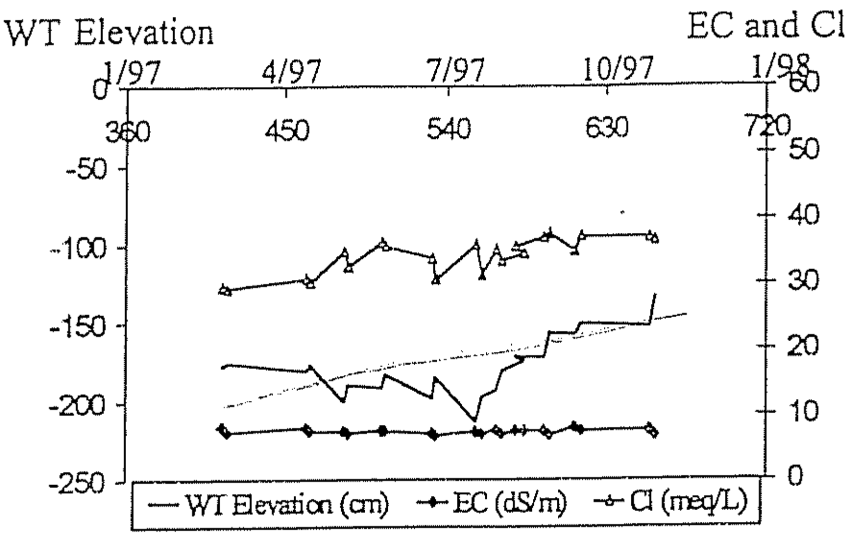


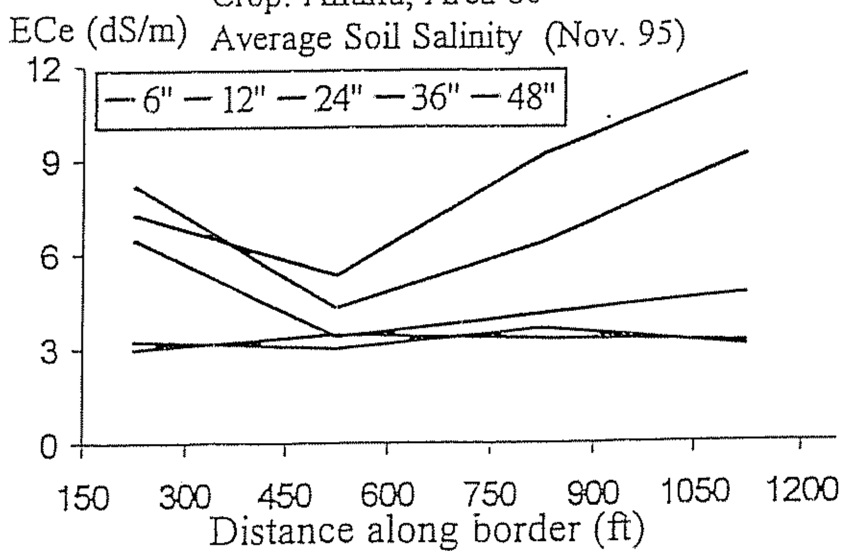
d
z
Surface
Subsurface
L
Surface
Subsurface
L



Crop: Alfalfa, Area 80
WT Elevation
EC and Cl
1/96
7/96
1/97
7/97
1/98
0
90
180
270
360
450
540
630
720
0
-50
-100
-150
-200
-250
60
50
40
30
20
10
0
WT Elevation (cm)
EC (dS/m)
Cl (meq/L)

DRAFT





Starting EC
No leaching prior to planting.

would like to see specific numbers related to this.

where's the EC of the standard field? Need to compare.

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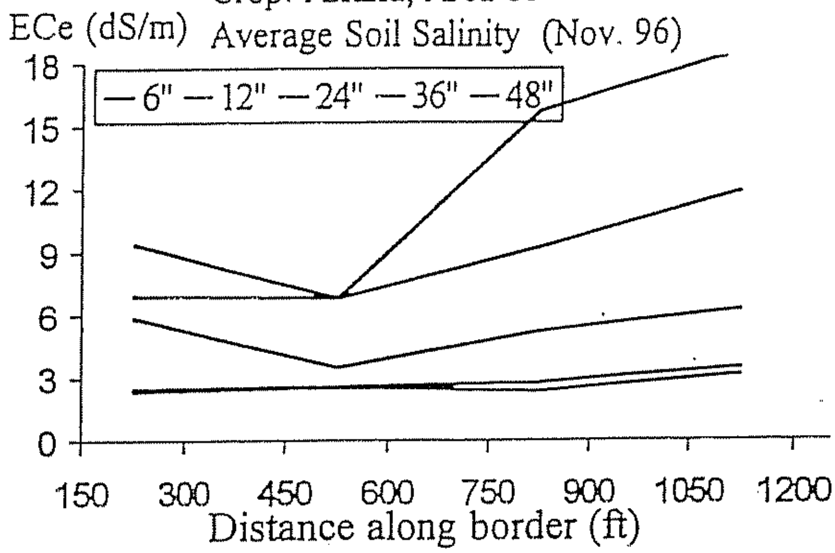
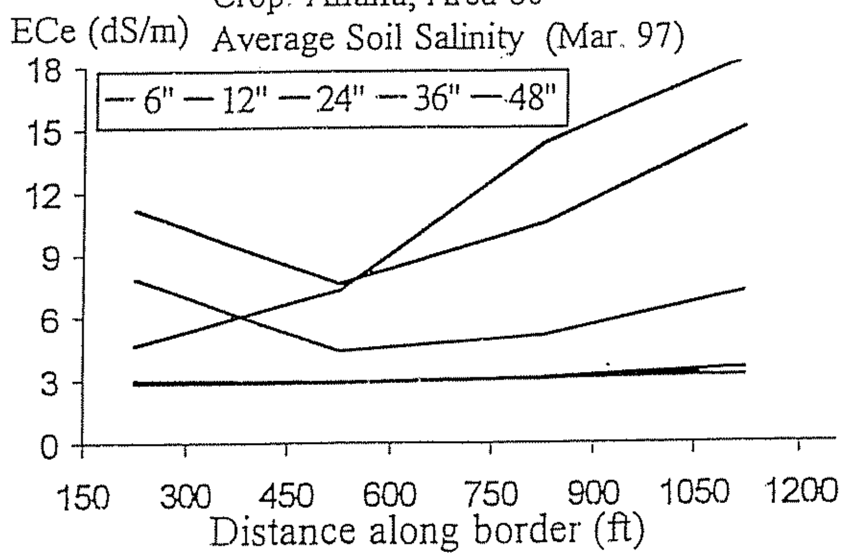
Crop: Alfalfa, Area 80
Average Soil Salinity (Nov. 96)

EC After 1 year

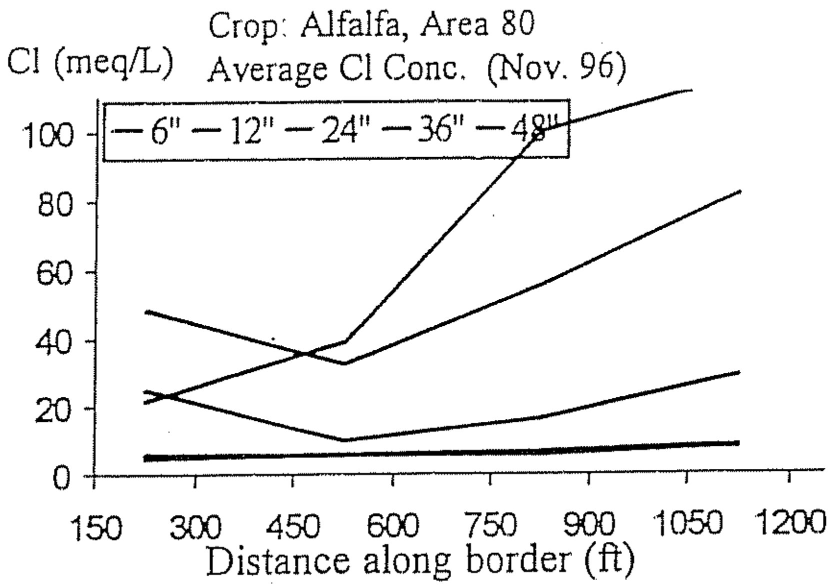


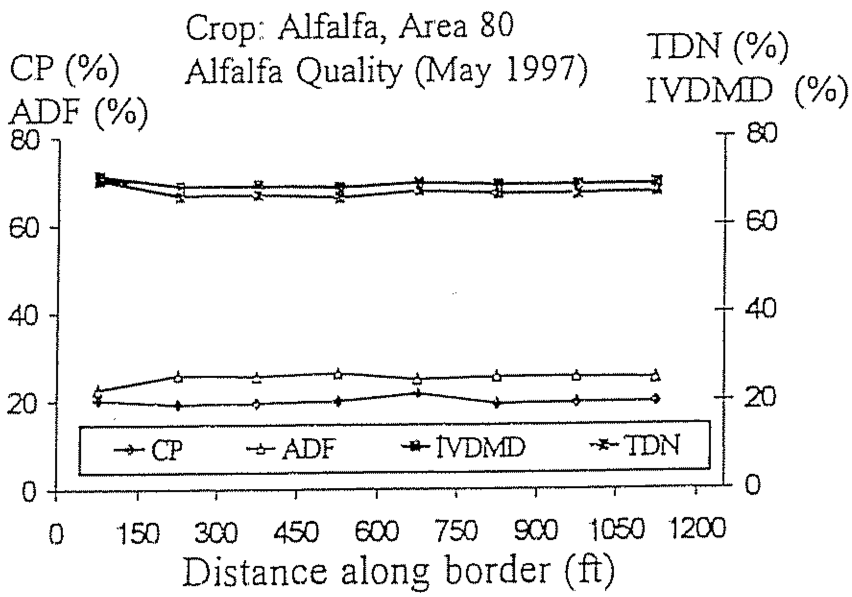
Crop: Alfalfa, Area 80
Average Soil Salinity (Mar. 97)

EC After 1.3 yr

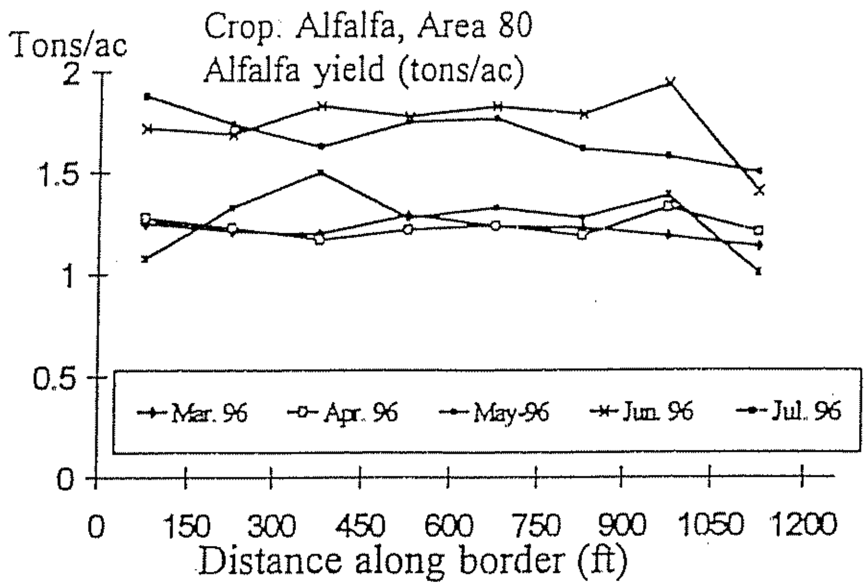


DRAFT

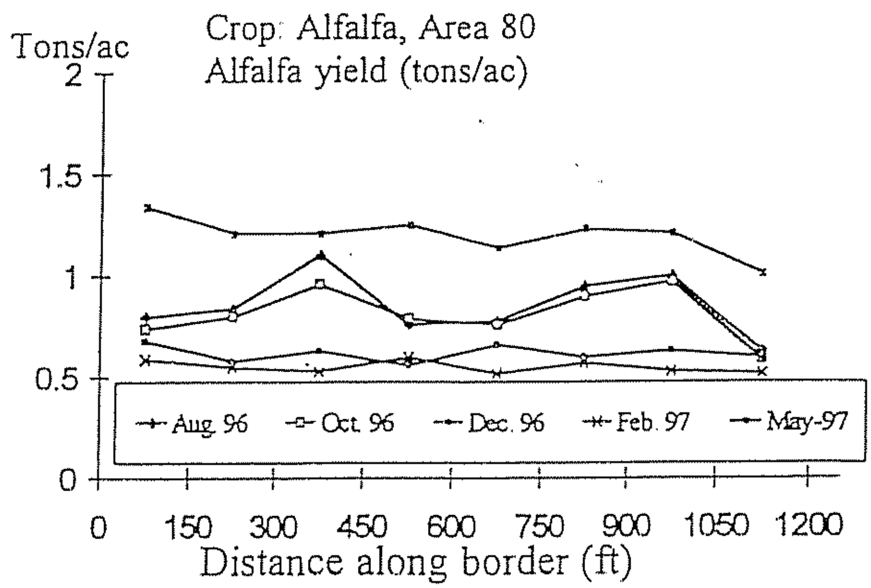

Crop: Alfalfa, Area 80
Cl (meq/L)
Average Cl Conc. (Nov. 96)
— 6" — 12" — 24" — 36" — 48"
100
80
60
40
20
0
150
300
450
600
750
900
1050
1200
Distance along border (ft)


Crop: Alfalfa, Area 80
Alfalfa Quality (May 1997)
CP (%)
ADF (%)
TDN (%)
IVDMD (%)
80
60
40
20
0
CP
ADF
IVDMD
TDN
0
150
300
450
600
750
900
1050
1200
Distance along border (ft)

DRAFT

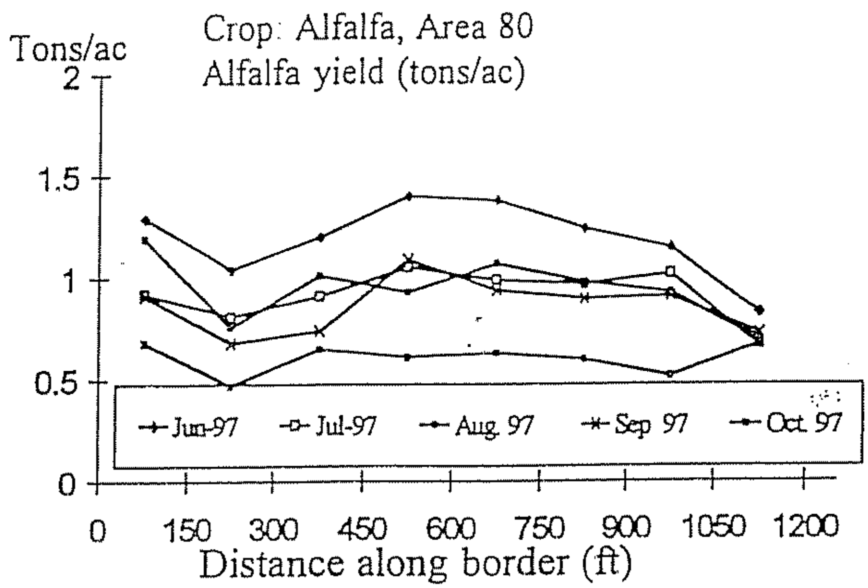


Crop: Alfalfa, Area 80
Alfalfa yield (tons/ac)
Tons/ac
2
1.5
1
0.5
0
Mar. 96
Apr. 96
May-96
Jun. 96
Jul. 96
0
150
300
450
600
750
900
1050
1200
Distance along border (ft)

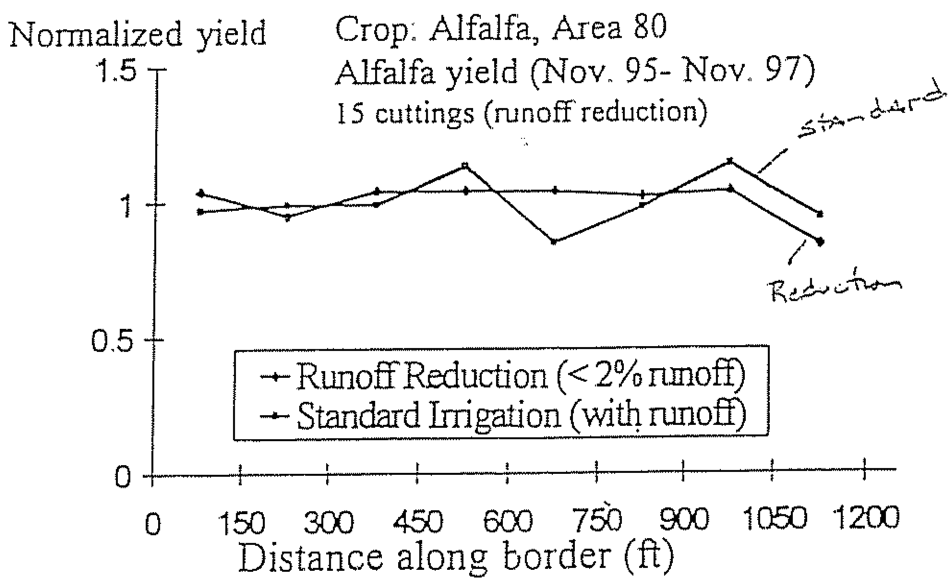


Crop: Alfalfa, Area 80
Alfalfa yield (tons/ac)
Tons/ac
2
1.5
1
0.5
0
Aug. 96
Oct. 96
Dec. 96
Feb. 97
May-97
0
150
300
450
600
750
900
1050
1200
Distance along border (ft)

DRAFT

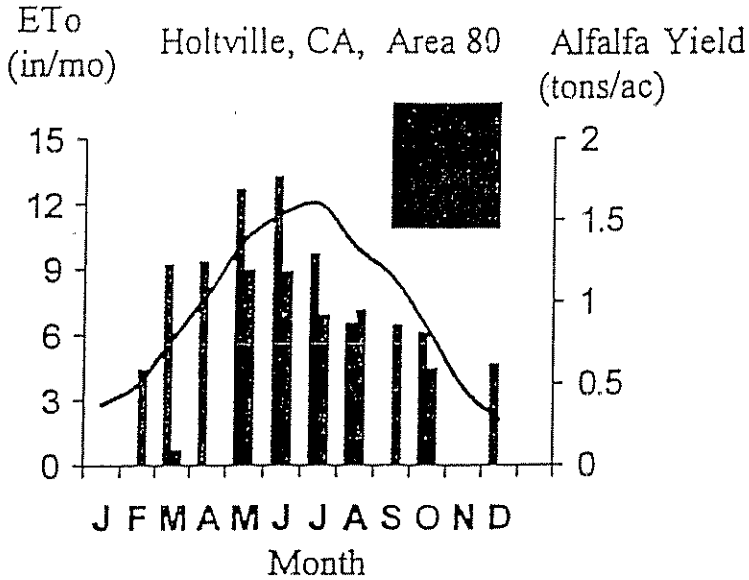


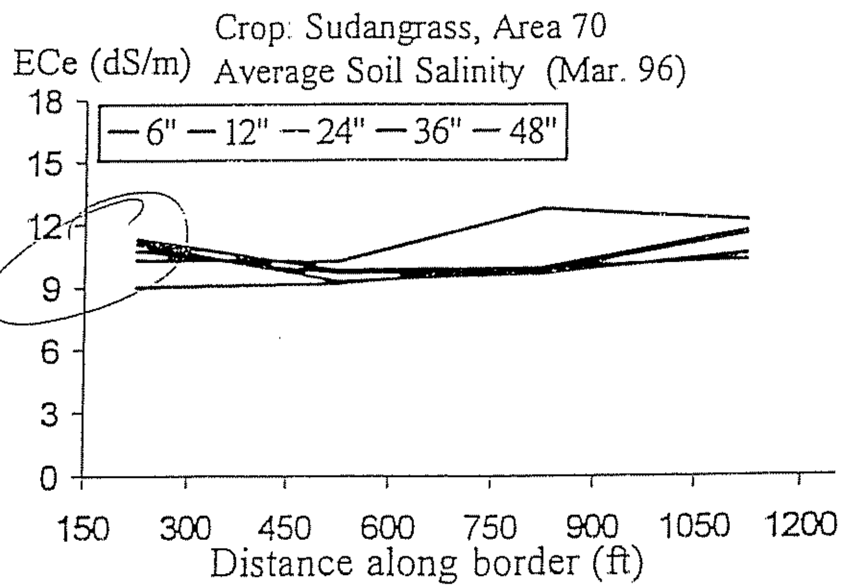
Crop: Alfalfa, Area 80
Alfalfa yield (tons/ac)
Tons/ac
2
1.5
1
0.5
0
Jun-97
Jul-97
Aug. 97
Sep 97
Oct. 97
0
150
300
450
600
750
900
1050
1200
Distance along border (ft)



Normalized yield
Crop: Alfalfa, Area 80
Alfalfa yield (Nov. 95- Nov. 97)
15 cuttings (runoff reduction)
standard
Reduction
1.5
1
0.5
0
Runoff Reduction (< 2% runoff)
Standard Irrigation (with runoff)
0
150
300
450
600
750
900
1050
1200
Distance along border (ft)

DRAFT





Leaching prior to planting?

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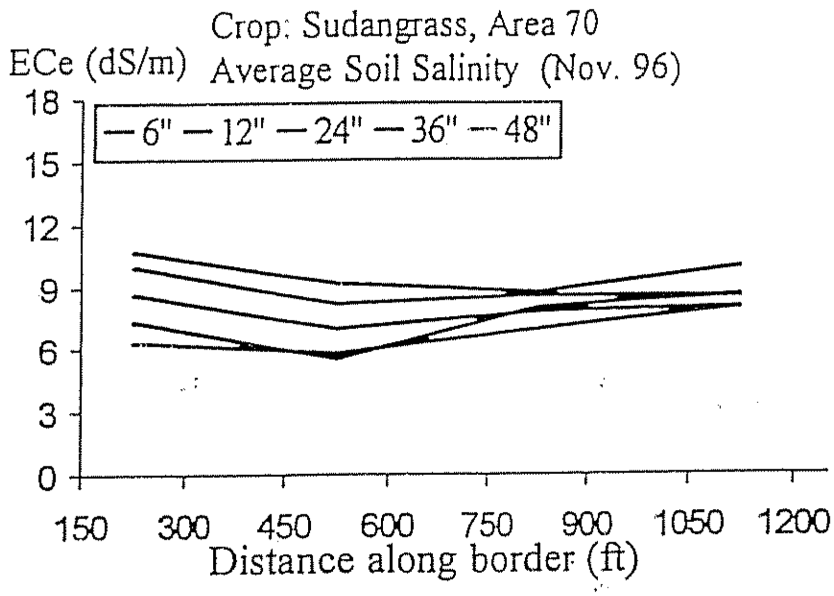

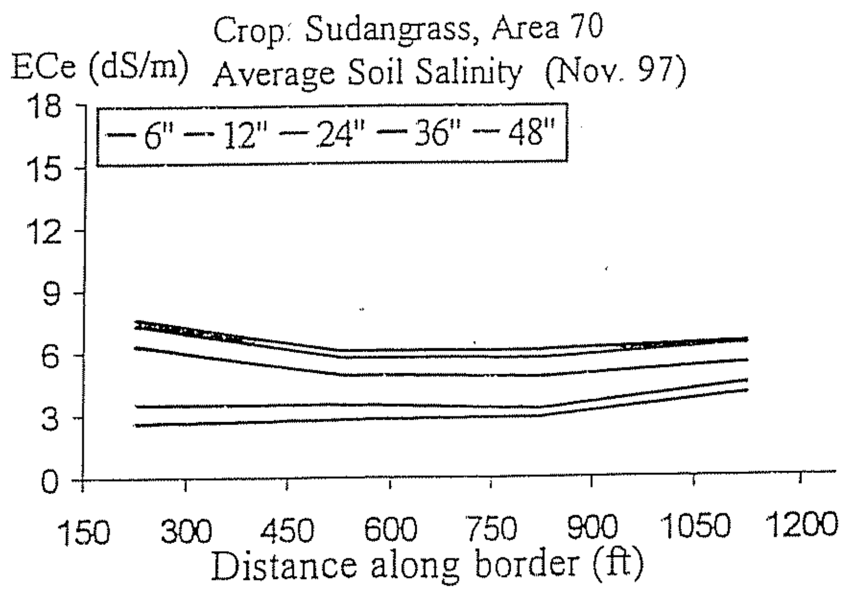

How can EC be dropping under a reduced R.O. study

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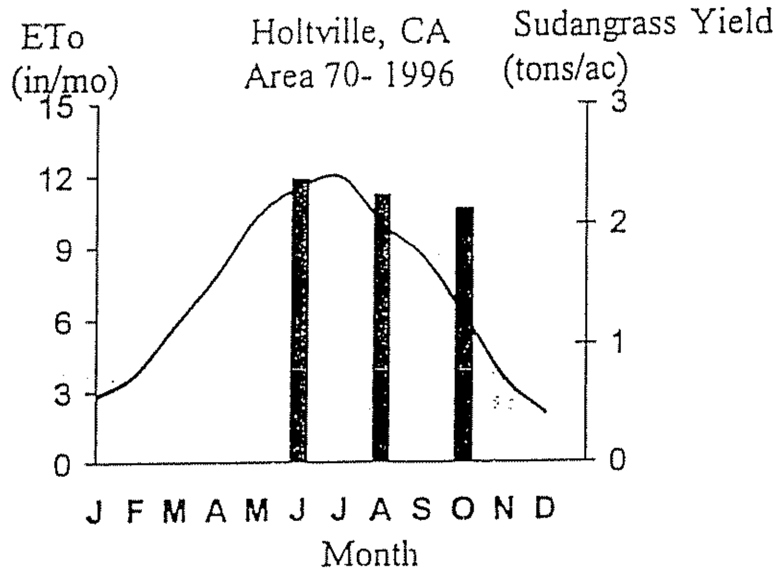
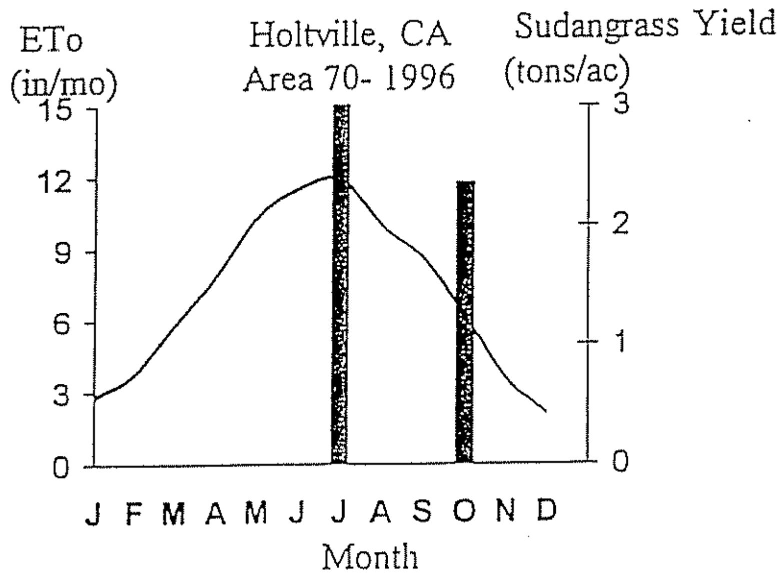
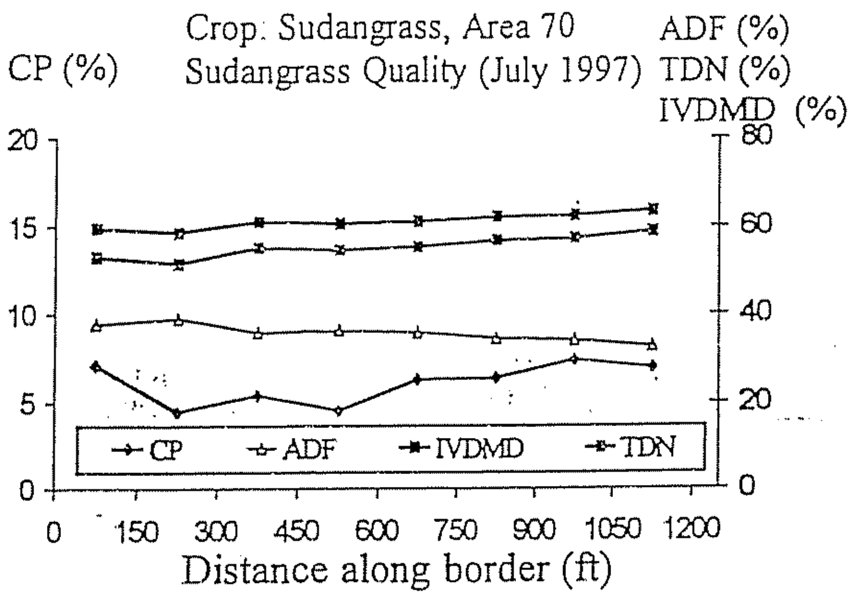

ETo
(in/mo)
Holtville, CA
Area 70- 1996
Sudangrass Yield
(tons/ac)
15
12
9
6
3
0
3
2
1
0
J F M A M J J A S O N D
Month


ETo
(in/mo)
Holtville, CA
Area 70- 1996
Sudangrass Yield
(tons/ac)
15
12
9
6
3
0
3
2
1
0
J F M A M J J A S O N D
Month

DRAFT



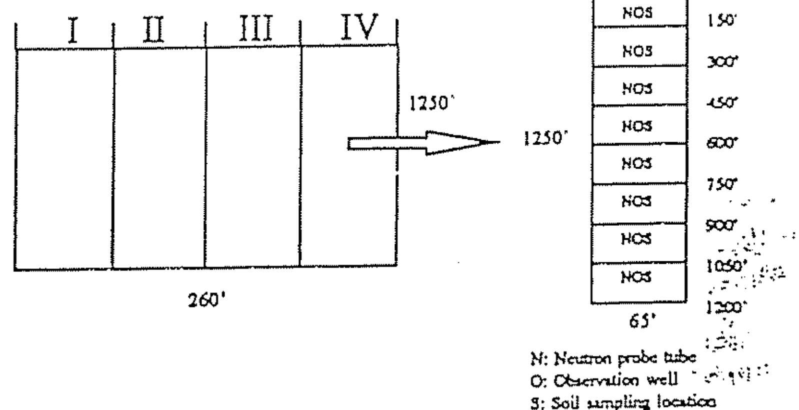
Crop: Sudangrass, Area 70
Sudangrass Quality (July 1997)
CP (%)
ADF (%)
TDN (%)
IVDMD (%)
20
15
10
5
0
80
60
40
20
0
CP
ADF
IVDMD
TDN
0
150
300
450
600
750
900
1050
1200
Distance along border (ft)

DRAFT

S ↑

Runoff Reduction Project
University of California Desert Research & Extension Center

Field No. 2 Sudangrass Area 70



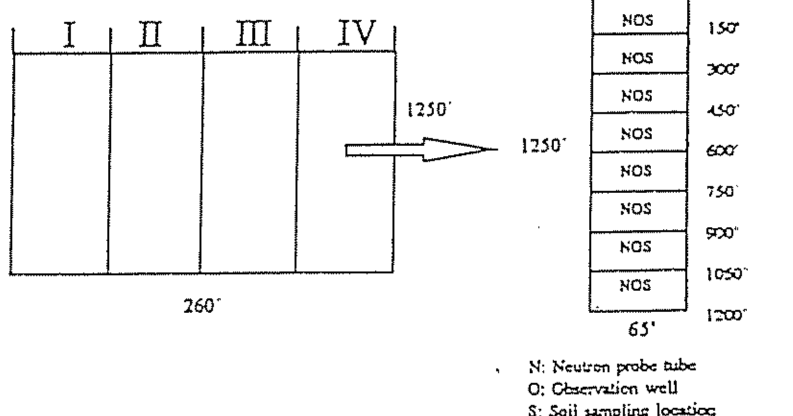
Map not to scale

Fig. 1- Schematic of the field layout

S ↑

Runoff Reduction Project
University of California Desert Research & Extension Center

Field No. 1 Alfalfa Area 80



Map not to scale

Fig. 1- Schematic of the field layout

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```
c 11/24/96
c 05/04/97
c 11/17/97
c //
      integer respond
      character*30 name, crop, tol
      integer a3,a4,a8,a9,b1b,b5a,b6,b7,b8a
      character*10 output, year, input,k1
      dimension a(60),b(60),c(60),id(60),p(10,10),x(40),iy(40)
        real lab

      write(6,*)'          '
      WRITE(6,*)'    ***********************************************'
      WRITE(6,*)'    ***********************************************'
      WRITE(6,*)'    ***                                        ***'
      write(6,*)'    ***  IRRIGATION MANAGEMENT & SURFACE RUNOFF ***'
      write(6,*)'    ***        REDUCTION PROGRAM  (SRRP)       ***'
      write(6,*)'    ***                                        ***'
      write(6,*)'    ***       "SRRP" ver. 1.0  APR. 1997"      ***'
      write(6,*)'    ***********************************************'
      write(6,*)'    DRAFT DRAFT DRAFT DRAFT DRAFT DRAFT DRAFT DRAFT '
      WRITE(6,*)'    ***********************************************'
      WRITE(6,*)'    ***********************************************'
      WRITE(6,*)' '
      CALL WAIT
      write(6,*)'     THE REGENTS OF THE UNIVERSITY OF CALIFORNIA MAKE'
      write(6,*)'     NO PRESENTATION OR WARRANTIES WITH RESPECT TO THE'
      write(6,*)'     CONTENTS HEREOF AND SPECIFICALLY DISCLAIM ANY'
      write(6,*)'     IMPLIED WARRANTIES OR MERCHANTABILITY OR FITNESS'
      write(6,*)'     FOR ANY PARTICULAR PURPOSE. Further, the Regents'
      write(6,*)'     of the University of California reserve the right'
      write(6,*)'     to revise this software and/or documentation and'
      write(6,*)'     to make changes from time to time in the content'
      write(6,*)'     hereof without obligation of the Regents of the'
      write(6,*)'     University of California to notify any person of'
      write(6,*)'     such revision or change.'
      write(6,*)' '
      write(6,*)'          K. M. Bali'
      write(6,*)'          Tel: 760-352-9474, Fax: 760-352-0846'
      write(6,*)'          E-mail: kmbali@ucdavis.edu'
      write(6,*)'     Copyright (c) 1997, Version 1.00'
      write(6,*)'     The Regents of the University of California'
      write(6,*)'     DOS Version Requires MS-DOS 5.00 or higher'
      write(6,*)'     Windows Version Requires MS Windows 95'
      write(6,*)' '
      call wait

cc SELECTION NO. 1
c    write(6,*)' '
100   write(6,*)'   This program estimates irrigation cutoff time to '
      write(6,*)'   reduce or eliminates surface runoff and predicts'
      write(6,*)'   irrigation efficiency parameters in the Imperial'
      write(6,*)'   Valley, CA. and estimates the relative yield of'
      write(6,*)'   alfalfa and sudangrass as a function of soil '
      write(6,*)'   salinity'
      write(6,*)' '
      write(6,*)'   1- Flow rate'
      write(6,*)'   2- Irrigation cutoff time and Application Eff.'
c      write(6,*)'   3-'
      write(6,*)'   3- Yield and salinity'

        write(6,*)'Please enter your selection '
        read(5,*) respond
c           if(respond.eq.5) goto  400
          if(respond.gt.5) then
               call wrong
               goto 100
```

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```
          endif
          if(respond.lt.1) goto 100

         if(respond.eq.1) call flow
         if(respond.eq.2) call cutoff
         if(respond.eq.3) call salinity


      call wait

      stop
      end

      subroutine wait
c      write(6,*)' '
      write(6,*)'     Press <Ret> or <Enter> to continue'
      read(5,*)
      return
      end


      subroutine wrong
      write(6,*)' '
      write(6,*)'Your selection is not valid, please try again'
      write(6,*)' '
      call wait
      return
      end

      subroutine copy
      k=9
      write(k,700)
700   format('Irrigation Management & Surface Runoff Reduction Program')
      write(k,*)'SRRP ver. 1.0  APR. 1997  K. M. Bali, UCCE'
      write(k,*)'Copyright (c) 1997, Version 1.00  DRAFT'
      return
      end

      subroutine end
      write(6,*)' '
      Write(6,*)'      HAVE A NICE DAY! '
      write(6,*)' '
      stop
      return
      end

        subroutine flow
c        character*30 crop, tol
        character*10 output
        dimension aq(40),aqq(40),v(40)

cc SELECTION NO. 1
      write(6,*)'   This program estimates flow rate from '
      write(6,*)'   irrigation outlets, using the calibration of'
      write(6,*)'   Tod et al., 1991 ASCE. Journal of Irrigation'
      write(6,*)'   & Drainage Engineering Vol. 117, No.4, 596-598'
        write(6,*)' '
      call wait
100     Write(6,*)'Please enter gate diameter or diameter of'
        write(6,*)'siphone in inches'
        write(6,*)' '
        read(5,*) gd
        write(6,*)' '
        k=6
111    if(k4.eq.2) k=9
        write(k,*)'========================================'
        write(k,700) gd
```

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```
 700      format(2x,'Gate diameter:',f5.2,' "',4x,'Flow Rate')
          write(k,*)'                           ----------------'
          write(k,*)' Head loss (inches)     cfs         m^3/s'
          write(k,*)'-------------------------------------------'
          dh=2
          do 10 i=1,16
          dh=dh+(.5)
 c a in m and q m^3/s
 c v in m/s  k=2.5
        v(i)=((7.848)*(dh*0.0254))**0.5
 c q in m^3/sec
        aq(i)=v(i)*((gd*0.0254/2)**2)*(22/7)
 c q in cfs
        aqq(i)=aq(i)*35.314667
         write(k,701) dh, aqq(i),aq(i)
 701     format(5x,f5.2,12x,f8.3,2x,f10.5)
 10      continue
         call wait
       write(6,*)'       ****************************************'
       write(6,*)'       **   1- Select a new diameter          **'
       write(6,*)'       **   2- Save information in a file     **'
       write(6,*)'       **   3- Exit/Return to main program    **'
       write(6,*)'       ****************************************'
       write(6,*)' '
         write(6,*)'Please enter your selection '
       read(5,*) k4
         if(k4.eq.3) go to 33
       if(k4.eq.1) goto 100
       if(k4.eq.2) then
           k=9
           write(6,*)'Please enter the file name'
           read '(A)', output
           open(unit=9,file=output,status='new')
           write(9,*)'File Name: ',output
                  call copy
            goto 111
       endif
33       return
         end

         subroutine cutoff
         character*30 crop
         character*10 output
c         dimension ae(40),ro(40),dpp(40)

cc SELECTION NO. 2
      write(6,*)'   This program estimates irrigation cutoff time'
      write(6,*)'   to eliminate or minimize runoff in clay soils'
      write(6,*)'   using the method of Grismer and Tod, 1994'
      write(6,*)'   California Agriculture, (48(4):33-36'
        write(6,*)' '
      write(6,*)' '
        write(6,*)'          '
100     write(6,*)'       1- Alfalfa   '
        write(6,*)'       2- Sudangrass'
c
      write(6,*)' '
        write(6,*)'Please select a crop'
          read(5,*) respond
        if(respond.eq.1) THEN crop="Alfalfa"
        if(respond.eq.2) THEN  crop="Sudangrass"
        write(6,*)'Please enter the desired depth of application'
        write(6,*)'in inches'
        read(5,*) dd
        write(6,*)'Please enter the border length (ft)'
        read(5,*) l
        write(6,*)'Please enter the border width (ft)'
```

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```
      read(5,*) w
      write(6,*)'Please enter field slope ft/1000'
      write(6,*)'Example: enter 0.001 for a 1 ft drop per 1000 ft'
      write(6,*)'or 0.002 for a 2ft drop per 1000 ft'
      read(5,*) s
      write(6,*)'Enter crop maturity factor'
      write(6,*)' 1- newly planted field'
      write(6,*)' 2- for crop height less than 5 inches'
      write(6,*)' 3- for crop height greater than 5 inches'
      read(5,*) i
      if(i.eq.1) an=0.015
      if(i.eq.2) an=0.023
      if(i.eq.3) an=0.031
      write(6,*)'Enter flow rate per border in cfs'
      read (5,*) aq
      write(6,*)'Enter advance distance in ft'
      read(5,*) lx
      write(6,*)'Enter advance time in minutes'
      read(5,*) t
      d= (aq*an)/(1.486*w*(s**0.5))
      d=d**0.6
      taw=aq*t*60
      sw=lx*w*d
      aiw=taw-sw
      z=aiw/(lx*w)
      ct=(l*w*z)/(aq*60)
      write(6,*)'------------------------'
      di=z*12
      write(6,769) di
 769  format(' Infiltrated water depth: ',f6.2,' inches')
      write(6,771) ct
 771  format(' Cutoff time: ',f6.0,' minutes')
c  deep percolation depth
      dp=di-dd
      if(dp.le.0) dp=0
c     time increments  10 minutes
      write(6,*)' '
      write(6,*)'Irrigating time    App. Eff.   Deep Perc.  Runoff'
      write(6,*)'--(minutes)----   -------------(%)--------------'
      do 20 i=0,12
      ti=ct+(i*10)
      if(dd.lt.di) then
        ae=(100*(dd/12)*l*w)/(aq*ti*60)
      end if
      if(dd.ge.di) then
        ae=(100*(di/12)*l*w)/(aq*ti*60)
      endif
      dpp=100*(dp/12)*l*w/(aq*ti*60)
      ro=100*(ti-ct)*aq*60/(aq*ti*60)
      if(ro.gt.25) goto 20
      write(6,768) ti, ae, dpp, ro
768   format(4x,f8.0,2x,3(3x,f8.1))
20    continue
772   call wait
    write(6,*)'       ****************************************'
    write(6,*)'       **   1- Select a new border          **'
    write(6,*)'       **   2- Save information in a file   **'
    write(6,*)'       **   3- Exit/Return to main program  **'
    write(6,*)'       ****************************************'
    write(6,*)' '
      write(6,*)'Please enter your selection '
    read(5,*) k4
      if(k4.eq.3) go to 33
    if(k4.eq.1) goto 100
    if(k4.eq.2) then
       k=9
       write(6,*)'Please enter the file name'
```

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```
          read '(A)', output
          open(unit=9,file=output,status='new')
          write(9,*)'File Name: ',output
                write(9,*)'Crop: ',crop
                call copy
        write(9,*)' '
        write(9,*)'----------------------------------------'
        write(9,900) l
 900    format(' Border length (ft):  ', i6)
        iw=w
        write(9,901) iw
 901    format(' Border width (ft):   ', i6)
        write(9,902) s
 902    format(' Field slope (ft/ft):   ', f6.4)
        write(9,903) an
 903    format(' Crop maturity factor:   ', f6.4)
        write(9,904) aq
 904    format(' Flow rate per border in cfs: ',f6.3)
        write(9,905) lx
 905    format(' Advance distance in ft: ', i6)
        write(9,906) t
 906    format(' Advance time in minutes: ',f6.0)
        write(9,907) dd
 907    format(' Desired application depth (in): ',f6.2)
        write(9,*)'-----------------------------'
        write(9,769) di
 c769    format(' Infiltrated water depth: ',f6.2)
      write(9,*)'Estimated cutoff time to reduce or eliminate'
      write(9,910) ct
 910  format(' surface runoff: ',f7.0,' minutes')
 c  deep percolation depth
        dp=di-dd
        if(dp.le.0) dp=0
 c      time increments  10 minutes
        write(9,*)' '
        write(9,*)'Irrigating time    App. Eff.   Deep Perc.  Runoff'
        write(9,*)'--(minutes)----    -------------(%)---------------'
        do 30 i=0,7
        ti=ct+(i*10)
        if(dd.lt.di) then
          ae=(100*(dd/12)*l*w)/(aq*ti*60)
        end if
        if(dd.ge.di) then
          ae=(100*(di/12)*l*w)/(aq*ti*60)
        endif
        dpp=100*(dp/12)*l*w/(aq*ti*60)
        ro=100*(ti-ct)*aq*60/(aq*ti*60)
        if(ro.gt.25) goto 30
        write(9,768) ti, ae, dpp, ro
c768     format(4x,f8.0,2x,3(3x,f8.1))
30      continue

      goto 772
      endif
33      return
        end


        subroutine salinity
        character*30 crop, tol
        character*10 output
        dimension x(40),iy(40)

cc SELECTION NO. 4
     write(6,*)'   The relationship between relative yield and average'
     write(6,*)'   rootzone salinity (dS/m) can be expressed as:'
     write(6,*)' '
```

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```
      write(6,*)'                    Y=100-B(ECe-A)'
      write(6,*)' '
      write(6,*)'   where Y= relative yield (percentage of the yield of'
      write(6,*)'            the crop grown under saline conditions'
      write(6,*)'            relative to that obtained under nonsaline)'
      write(6,*)' '
      write(6,*)'         A= threshold level of soil salinity '
      write(6,*)'            at which yield decreases begin'
      write(6,*)'            (at which 100% yield occurs)'
      write(6,*)' '
      write(6,*)'         B=% reduction in yield per unit increase'
      write(6,*)'             in salinity in excess of A'
      WRITE(6,*)' '
      write(6,*)'         ECe= average rootzone salinity'
      write(6,*)' '
      call wait
100     write(6,*)'     1- ALFALFA'
        WRITE(6,*)'     2- SUDANGRASS'
        write(6,*)'     3- WHEAT'
        write(6,*)'     4- ADD A CROP'
        write(6,*)'     5- Salinity/Concentration Conversion Factors'
      write(6,*)' '
      write(6,*)'Please enter your selection '
      read(5,*) respond
           if(respond.eq.5) goto  401
           if(respond.gt.5) then
         call wrong
         goto 100
        endif
        if(respond.lt.1) goto 100

        if(respond.eq.1) THEN
                an=2.0
                bn=7.3
                crop="Alfalfa"
                tol="MS"
        ENDIF
        if(respond.eq.2) THEN
                an=2.8
                bn=4.3
                crop="Sudangrass"
                tol="MT"
        ENDIF
        if(respond.eq.3) THEN
                an=5.9
                bn=3.8
                crop="Wheat"
                tol="T"
        endif
           if(respond.eq.4) THEN
         write(6,*)'Please enter the value of A'
         read(5,*) an
         write(6,*)'Please enter the value of B'
         read(5,*) bn
         write(6,*)'Please enter crop name'
         read '(A)', crop
         tol="U"
       endif
     k=6
     k4=0
111   if(k4.eq.2) k=9
     write(k,*)'Crop: ',crop
     if(tol.eq."S") write (k,*)'Tolerance level: Sensitive'
     if(tol.eq."MS") write(k,*)'Tolerance level: Moderately sensitive'
     if(tol.eq."MT") write(k,*)'Tolerance level: Moderately tolerant'
     if(tol.eq."T") write(k,*)'Tolerance level: Tolerant'
     if(tol.eq."U") write(k,*)'Tolerance level:'
```

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```
      write(k,778) an,bn
 778  format(' Threshold Salinity, A=',f5.1,' dS/m  ',' Slope, B=',f5.1
     *, '%')
      if(k.eq.9) write(K,*)' '
 8       write(k,800)
 800    format('=========================================')
      write(k,*)' ECe  (dS/m)          Relative Yield (%)'
      write(k,800)
      write(k,779) an
 779    format('  ECe < ',f5.2,'                     100')
      ian=an+1

      fact=1
           if(bn.gt.8) fact=0.5
           if(bn.gt.15) fact=0.25
           if(bn.gt.20) fact=0.2
           if(bn.lt.5) fact=4

           if(ian.eq.an+1) ian=an

      do 530 i=1,30
      x(i)=ian+(i-1)*fact
      iy(i)=100-  (bn*(x(i)-an))
         if (iy(i).lt.40) then
         n=i
         goto 530
         endif
            write(k,903) x(i), iy(i)
 530    continue
 903    format(8x,f5.2,16x,i4)
      write(k,800)
      write(k,*)'ECe: average rootzone salinity (dS/m)'
      call wait

 402     write(6,*)' '

      write(6,*)'       ****************************************'
      write(6,*)'       **   1- Select a new crop             **'
      write(6,*)'       **   2- Save information in a file    **'
      write(6,*)'       **   3- Salinity/Concentration        **'
      write(6,*)'       **        conversion factors          **'
      write(6,*)'       **   4- Exit/Return to main program   **'
      write(6,*)'       ****************************************'
      write(6,*)' '
        write(6,*)'Please enter your selection '
      read(5,*) k4
        if(k4.eq.4) go to 33
      if(k4.eq.1) goto 100
      if(k4.eq.2) then
          k=9
          write(6,*)'Please enter the file name'
          read '(A)', output
          open(unit=9,file=output,status='new')
          write(9,*)'File Name: ',output
                call copy
           goto 111
      endif
 400    if(respond.eq.25) k4=3
      if(k4.eq.3) then
 401     kk=6
      write(kk,*)'Salinity/Concentration Conversion Factors'
      write(kk,*)' '
      write(kk,*)'***********************************************'
      write(kk,*)'**  1 ppm = 1 mg/L  (for low concentrations) **'
      write(kk,*)'**  1 ppb (part per billion) = 1 µg/L        **'
      write(kk,*)'**  1 ppm = 1000 ppb                         **'
      write(kk,*)'**  1 mg/L = 1000 µg/L                       **'
```

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```
      write(kk,*)'**********************************************'
      write(kk,*)'**  1 dS/m = 1 mmhos/cm                     **'
      write(kk,*)'**  1 dS/m = 640 ppm ;                      **'
      write(kk,*)'**               if EC is less than 5 dS/m  **'
      write(kk,*)'**  1 dS/m = 800 ppm ;                      **'
      write(kk,*)'**               if EC is greater than 5 dS/m **'
      write(kk,*)'**  1 ton/ac-ft = 735 ppm                   **'
      write(kk,*)'**               if EC is less than 5 dS/m  **'
      write(kk,*)'**  1 ton/ac-ft = 1.15 dS/m                 **'
      write(kk,*)'**********************************************'
      if (kk.eq.6) call wait
      write(kk,*)'**********************************************'
      write(kk,*)'**   Calcium (Ca)     1 meq/L = 20.04 mg/L  **'
      write(kk,*)'**   Chloride (Cl)    1 meq/L = 35.45 mg/L  **'
      write(kk,*)'**   Magnesium (Mg)   1 meq/L = 12.15 mg/L  **'
      write(kk,*)'**   Nitrate (NO3)    1 meq/L = 62.00 mg/L  **'
      write(kk,*)'**   Sodium (Na)      1 meq/L = 22.99 mg/L  **'
      write(kk,*)'**********************************************'
      IF(KK.EQ.6) CALL WAIT
      write(kk,*)'Note that EC is affected by temperature. EC25 is '
      write(kk,*)'most commonly used to express the electrical '
      write(kk,*)'conductivity at 25 C (77 F). Measurements made at'
      write(kk,*)'other temperatures should be adjusted to EC25 using'
      write(kk,*)'the following equation:'
      write(kk,*)' '
      write(kk,*)'EC25=ECT - 0.02 (T-25) ECT'
      write(kk,*)' '
      write(kk,*)'where ECT is the EC at temperature T'
      write(kk,*)'          (T should be in centigrade)'
      write(kk,*)'Example: If water"s temperature is 30 C and EC is'
      write(kk,*)'7 dS/m, calculate EC25.'
      write(kk,*)'Using the above equation:'
      write(kk,*)'      EC25=7 - 0.02 (30-25) 7'
      write(kk,*)'      EC25=7 - 0.7 = 6.3 dS/m'
      if (kk.eq.6) then
      write(6,*)'     ***************************************'
      write(6,*)'     **   1- Select a new crop            **'
      write(6,*)'     **   2- Save information in a file   **'
      write(6,*)'     **   3- Exit/Return to main program  **'
      write(6,*)'     ***************************************'
      write(6,*)' '
        write(6,*)'Please enter your selection '
      read(5,*) k4

      if(k4.eq.1) goto 100
      if(k4.eq.2) then
          write(6,*)'Please enter the file name'
          read '(A)', output
          open(unit=8,file=output,status='new')
          write(8,*)'File Name: ',output
          kk=8
          goto 401
      endif
        if(k4.eq.3) go to 33
      endif
      endif
      if(kk.eq.8) go to 402
c     if(k4.eq.3) call end

33      return
        end
```

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Examples of program output

File Name: flow
Irrigation Management & Surface Runoff Reduction Program
SRRP ver. 1.0 APR. 1997 K. M. Bali, UCCE

Gate diameter: 12.00 "	Flow Rate	
Head loss (inches)	cfs	m^3/s
2.50	1.737	.04919
3.00	1.903	.05388
3.50	2.055	.05820
4.00	2.197	.06222
4.50	2.330	.06599
5.00	2.457	.06956
5.50	2.576	.07296
6.00	2.691	.07620
6.50	2.801	.07931
7.00	2.907	.08231
7.50	3.009	.08520
8.00	3.107	.08799
8.50	3.203	.09070
9.00	3.296	.09333
9.50	3.386	.09588
10.00	3.474	.09838

File Name: cutoff
Crop: Alfalfa
Irrigation Management & Surface Runoff Reduction Program
SRRP ver. 1.0 APR. 1997 K. M. Bali, UCCE

Border length (ft): 1200
Border width (ft): 65
Field slope (ft/ft): .0010
Crop maturity factor: .0310
Flow rate per border in cfs: 2.600
Advance distance in ft: 540
Advance time in minutes: 131.
Desired application depth (in): 5.00

Infiltrated water depth: 5.63 inches
Estimated cutoff time to reduce or eliminate
surface runoff: 235 minutes

cfs × hrs = Ac × in

$2.6 \times \frac{235}{60} = 10.2$ Ac-in

$\frac{10.2 \text{ Ac-in}}{\frac{65 \times 1200}{43560}} = 5.69$ inches

Irrigating time (minutes)	App. Eff. (%)	Deep Perc. (%)	Runoff (%)
235.	88.8	11.2	.0
245.	85.2	10.8	4.1
255.	81.8	10.3	7.9
265.	78.7	9.9	11.3
275.	75.9	9.6	14.6
285.	73.2	9.2	17.6
295.	70.7	8.9	20.4
305.	68.4	8.6	23.0

File Name: alfalfa
Irrigation Management & Surface Runoff Reduction Program
SRRP ver. 1.0 APR. 1997 K. M. Bali, UCCE

Crop: Alfalfa
Tolerance level: Moderately sensitive
Threshold Salinity, A= 2.0 dS/m Slope, B= 7.3%

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ECe (dS/m)	Relative Yield (%)
ECe < 2.00	100
2.00	100
3.00	92
4.00	85
5.00	78
6.00	70
7.00	63
8.00	56
9.00	48
10.00	41

ECe: average rootzone salinity (dS/m)

File Name: sudan
Irrigation Management & Surface Runoff Reduction Program
SRRP ver. 1.0 APR. 1997 K. M. Bali, UCCE
Copyright (c) 1997, Version 1.00 DRAFT
Crop: Sudangrass
Tolerance level: Moderately tolerant
Threshold Salinity, A= 2.8 dS/m Slope, B= 4.3%

ECe (dS/m)	Relative Yield (%)
ECe < 2.80	100
3.00	99
7.00	81
11.00	64
15.00	47

ECe: average rootzone salinity (dS/m)

9-16

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OFFICE OF THE VICE PRESIDENT—
AGRICULTURE AND NATURAL RESOURCES

OFFICE OF THE PRESIDENT
Division of Agriculture and Natural Resources
300 Lakeside Drive, 6th Floor
Oakland, California 94612-3560

November 7, 1997

Dr. Fawzi Karajeh
Program Manager, Agricultural Drainage Reduction
Office of Water Conservation
California Department of Water Resources
1020 Ninth Street, 3rd Floor
Sacramento, CA 95814

On behalf of The Regents of the University of California and Vice President W.R. Gomes, enclosed is a copy of the proposal entitled "Irrigation and Drainage Management and Surface Runoff Reduction in the Imperial Valley; On-Farm Irrigation Management and Surface Runoff Reduction". The Project Leader is Khaled Bali, Cooperative Extension Farm Advisor located in Imperial County.

Any questions concerning the project work should be directed to Mr. Bali at (619) 352-9474. Questions regarding administrative matters such as contracts or other award documents should be directed to my attention at: University of California, Division of Agriculture and Natural Resources, 300 Lakeside Drive, 6th Floor, Oakland, CA 94612-3560.

Sincerely,

Carol Berman

Carol Berman
Contracts and Grants Coordinator
(510) 987-0050
/ht

12/2/97

c: K. Bali/Imperial County
R. Gonzalez/Imperial County
A. Smith
without enclosure

COOPERATIVE EXTENSION
UNIVERSITY OF CALIFORNIA
IMPERIAL COUNTY

1050 E. HOLTON ROAD
HOLTVILLE, CA 92250-9615
TELEPHONE (619) 352-9474
FAX NUMBER (619) 352-0846

October 28, 1997

Dr. Fawzi Karajeh
Program Manager, Agricultural Drainage Reduction
Office of Water Conservation
California Department of Water Resources
1020 Ninth Street, 3rd Floor
Sacramento, CA 95814

Dear Dr. Karajeh:

Enclosed please find a copy of our research proposal, "Irrigation and Drainage Management and Surface Runoff Reduction in the Imperial Valley; On-Farm Irrigation Management and surface Runoff Reduction" which we are submitting for review by your office. The attached project is our proposed extension of our current research and demonstration project in irrigation management in the Imperial Valley.

The objective of the attached amendment is to expand the current project to include commercial fields. The main focus of this study is to develop and demonstrate the use of a volume balance method to predict irrigation cutoff time to reduce surface runoff in the Imperial Valley. The proposed amendment is a result of our discussion with our current Project Advisory Committee, IID, USBR, and your office. I have sent a draft of the attached amendment to IID and USBR and have revised the scope of work to reflect their recommendations.

adoption ? of

The focus of this proposed expansion is to evaluate the potential benefits and risks associated with the adaption of our runoff reduction method. The project is also designed to evaluate the performance surface irrigation systems under the current irrigation practices in the Imperial Valley. The specific objectives of this project are outlined on page three of the attached proposal.

Currently, we are monitoring ten commercial alfalfa fields (five locations) for potential inclusion in the study. These fields were selected by the IID. The budget of the attached amendment covers the costs of studying eight alfalfa and sudangrass fields ranging in size from 30-80 acres per field. We feel that the information generated from monitoring eight fields will be adequate to achieve the objectives of the project. However, we will consider the possibility of reducing or increasing the number of fields that will be included in this study. In order for us to proceed with the attached work plan, we would like to get a response from your office and the cosponsor of the project (IID and USBR) by December 31, 1997.

Please let me know if you have any further questions or comments (Tel: 760-352-9474, Fax: 760-352-0846, E-mail: kmbali@ucdavis.edu). Thank you for your time and consideration.

Sincerely,

Khaled Bali

Khaled M. Bali
Farm Advisor
Irrigation/Water Management

c: Eldon Moore, IID
Imperial Irrigation District
P. O. Box 937
Imperial, CA 92251
Steve Jones, USBR
USBR, Water Conservation & Advisory Center
Lower Colorado Regional Office
P O BOX 61470
Boulder City, NV 89006-1470

Project Title: On-Farm Irrigation Management and Surface Runoff Reduction

Location: Imperial Valley

Duration: November 16, 1997 to December 31, 2000 → 25 1/2 months

Budget: The current project (July 1995-December 1998) is funded by California Department of water Resources (DWR), United States Bureau of Reclamation (USBR), and Imperial Irrigation District (IID). The cost of this Amendment will be covered by IID for the alfalfa fields (subject to IID's approval) and by USBR for the sudangrass fields (subject to USBR's approval)

Amendment to:

Irrigation and Drainage Management and Surface Runoff Reduction
in the Imperial Valley

Principal Investigators:

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1 Introduction:

Colorado River water is the only source of irrigation and drinking water in the Imperial Valley. About 2.8-3.0 million acre-feet of water are used every year to irrigate more than 500,000 acres of lands in the Imperial Valley. Approximately 17% of the delivered irrigation water in the Imperial Valley becomes tailwater runoff. All surface and subsurface drainage water enters the Salton Sea which has been serving as a drainage sink for the Imperial and Coachella Valleys since its formation in 1905. The Salton Sea continues to exist because of the drainage water from agriculture in Imperial and Coachella Valleys as well as flow of agricultural drainage and untreated and partially treated sewage from the Mexicali Valley. Because of drainage and its impact on the Sea, several water quality issues exist in the Imperial Valley for which water conservation plays a role. ?

The objective of the current project is to conduct a research and demonstration program that will improve irrigation efficiency, reduce surface runoff, utilize the shallow saline water table for new and improved irrigation and drainage management practices, determine crop coefficients for two common field crops (alfalfa and sudangrass) and increase utilization of CIMIS for irrigation scheduling. The focus of the current project is on the development and demonstration of a new method to predict irrigation cutoff time from pre-determined soil moisture status of the clay soil of interest. Issues related to salinity, irrigation management, and water quality will also be addressed in this project. Since soil salinity and water management are affected by water table depth, a major part of this study will be to quantify the effect of water table control on soil salinity, water infiltration rates, and irrigation efficiency. To observe cumulative effects of water table on soil salinity and consumptive water use, this study is conducted for three years (1995-1998). **Early results from this research and demonstration project show a ~~reduction in~~ alfalfa yield in the second year as a result of a combination of surface runoff reduction and one-irrigation per cutting irrigation treatment. However, a significant amount of water was saved as a result of reduced surface runoff and one-irrigation per cutting treatment. Sudangrass yield was not affected as a result of the surface runoff reduction treatment which resulted in significant water savings.** In the demo site only?

must see the results

The objective of this Amendment is to expand the current project to include commercial fields. The main focus of this study is to develop and demonstrate the use of a volume balance method to predict irrigation cutoff time to reduce surface runoff to approximately 5% or less of the applied water. Issues related to salinity, hay yield and quality, and water quality will be addressed in this project. Our work will fo~~cus on field crops,~~ specifically alfalfa and sudangrass. Field crops account for almost 80% of the 500,000 acres of irrigated land in the Imperial Valley and alfalfa and sudangrass rank first and third, respectively, in terms of harvested acreage of field crops (1996 Imperial County Agricultural Crop and Livestock report). These two major field crops were grown on ~~more~~ than 244,000 acres of irrigated lands in the Imperial Valley in 1996.

? correct

2 Objectives:

The specific objectives of this Amendment are:
1- Determine the best management practices (BMP's) for surface runoff reduction in heavy clay and silty clay soils of the Imperial Valley.
2- Determine the crop coefficients for alfalfa and sudangrass under current irrigation practices in the Imperial Valley. Why? Hasn't this been done yet?
3- Determine the crop coefficients for alfalfa and sudangrass under deficit and reduced runoff irrigation practices in the Imperial Valley. if any
4- Determine the contribution of shallow saline water tables to crop evapotranspiration in heavy clay and silty clay soils of the Imperial Valley.
5- Determine the effect of deficit and reduced irrigation practices on hay yield and quality. Isn't this done?
6- Evaluate the effect of deficit and reduced irrigation practices on soil salinity and water quality.
7- Develop a relatively simple approach to predict irrigation cutoff time from pre-determined soil moisture measurements for light and heavy soils of the Imperial Valley.

What good is prediction in irrigation. Cut-off time is a moving target. Charts exist for this now.

3 Procedures

3.1 Irrigation treatments

A total of four to six locations will be selected to conduct this experiment. **The budget of this amendment is for two alfalfa locations and two sudangrass locations.** Each location will contain two fields (30-80 acres). Each location will contain two irrigation treatments: standard irrigation (Field A) and a level of reduced irrigation treatment (Field B). Irrigation scheduling will be determined by the grower for the standard irrigation treatment (Field A) and by the project for the reduced irrigation treatment (Field B). The project will determine and order the water needed, through the grower, for the reduced irrigation treatment. who's standard

who pays for loss in yields

3.2 Alfalfa

3.2.1 Possible alfalfa locations

- Alamitos 27
  Area: Field A: 35 acres, Field B: 35 acres
  Soil type: 110, 115, and 122
  Grower: Labrucherie

- Elder 12 & 14
  Area: Field A: 75 acres, Field B: 72 acres
  Soil type: 110 and 115
  Grower: Leimgruber

- Holt 86
  Area: Field A: 69 acres, Field B: 69 acres

Soil type: 110 and 115
Grower: Strahm

- North Date 72
  Area: Field A: 35 acres, Field B: 35 acres
  Soil type: 114, 115, and 122
  Grower: Newside

- North Date 59
  Area: Field A: 70 acres, Field B: 70 acres
  Soil type: 110 & 115
  Grower: Black Dog

Soil types: Holtville silty clay, wet (SCS soil type 110), Imperial silty clay, wet (SCS soil type 114), Imperial-Glenbar silty clay loams, wet (SCS soil type 115), and Meloland very fine sandy loam, wet (SCS soil type 122)

Alfalfa growing season (October 1997 - October 2000)
Planting rates and dates: Alfalfa will be planted in October or November 1997.
Pest control and harvesting: According to the commercial practices of alfalfa production in Imperial Valley. what is pest control cost on a stressed crop vs a non-stressed crop?

Location 1 Alfalfa (fields A & B)

How does "good" grower vs "bad" grower fit in this?

Field A: Standard irrigation practices in the Imperial Valley. All irrigation and cultural practices will be determined by the cooperating grower. The cooperating grower is expected to inform the project contact person of irrigation dates and hay cutting/baling dates at least 24 hours prior to each event. ?

NO — I agree (No)

Measurements:

Project staff and IID will measure the amount of applied water, surface runoff, and hay yield. Project staff will take the necessary measurements to evaluate irrigation efficiency, water use efficiency, hay yield and quality (crude protein, acid detergent fiber, and neutral detergent fiber). The following parameters will be determined:

- Average depth of applied water
- Soil moisture content prior to and after each irrigation event
- Water table depth prior to and after each irrigation event where in relation to tile lines?
- Water table salinity and chloride concentration prior to and after each irrigation event
- Surface runoff water during and after irrigation events
- Soil salinity (twice a year)
- Soil chloride content (twice a year)
- Average yield after each cutting
- Hay quality (twice a year)

is this enough? ✓

oo many ariables to raw any gnificant nclusions

How are you going to measure SMD in a field with varying degrees of infiltrated water?

In tons, # bales ....?

How will changing irrigators on a field affect results? What if regular irrigator gets sick and substitute is used?

- Drainage water salinity and chloride content When, how often?
- Estimate of drainage outflow in Q or Volume? with a recorder?

Field B: Reduced irrigation treatment I. Standard irrigation practices in the Imperial Valley except that runoff will be reduced from the current average of 17% of applied water to less than 5% of applied water after stand establishment. All irrigation and cultural practices will be determined by the cooperating grower **except that the project will determine and order the amount of water needed** for irrigation. The cooperating grower is expected to inform the project contact person of irrigation dates and hay cutting/baling dates at least 24 hours prior to each event.

This average may not be participating farmers average.

who?

Measurements:

Project staff and IID will measure the amount of applied water, surface runoff, and hay yield. Project staff will take the necessary measurements to evaluate irrigation efficiency, water use efficiency, hay yield and quality (crude protein, acid detergent fiber, and neutral detergent fiber). The following parameters will be determined:

- Average depth of applied water
- Soil moisture content prior to and after each irrigation event
- Water table depth prior to and after each irrigation event
- Water table salinity and chloride concentration prior to and after each irrigation event
- Surface runoff water during and after irrigation events
- Soil salinity (twice a year)
- Soil chloride content (twice a year)
- Average yield after each cutting
- Hay quality (twice a year)
- Drainage water salinity and chloride content
- Estimate of drainage outflow

To account for soil spatial variability one set of borders in this treatment will be irrigated similarly to treatment A.

Location 2 alfalfa (fields A & B)

Field A: Same as field A in Location 1 alfalfa

Measurements:

Same as field A in Location 1 alfalfa

Field B: Reduced irrigation treatment II. Standard irrigation practices in the Imperial Valley except that runoff will be reduced from the current average of 17% of applied water **to less than 5% of applied water after stand establishment and one irrigation per cutting between July and September**. All irrigation and cultural practices will be determined by the cooperating grower **except that the project will determine and order the amount of water needed**. The cooperating grower is expected to inform the project contact person of irrigation dates and hay cutting/baling dates at least 24 hours prior to each event.

Measurements:

Same as field B in Location 1 alfalfa

Location 3 alfalfa (fields A & B)

This is an additional possible location (not covered by the attached budget)

Field A: Same as field A in Location 1 alfalfa

Measurements:

Same as field A in Location 1 alfalfa

Field B: Reduced irrigation treatment III. Standard irrigation practices in the Imperial Valley except that runoff will be reduced from the current average of 17% of applied water **to less than 5% of applied water after stand establishment and one irrigation per cutting after the first cut and December 1998.** After December 1998, we will resume the standard runoff reduction on this treatment. All irrigation and cultural practices will be determined by the cooperating grower **except that the project will determine and order the amount of water needed.** The cooperating grower is expected to inform the project contact person of irrigation dates and hay cutting/baling dates at least 24 hours prior to each event. ?

Measurements:

Same as field B in Location 1

3.3 Sudangrass:

3.3.1 Possible sudangrass locations

Sudangrass locations will be selected in March 1998

Sudangrass growing season (April - November)
Planting rates and dates: Sudangrass will be planted in April 1998.
Pest control and harvesting: According to the commercial practices of sudangrass production in Imperial Valley.

The experiment will be conducted on the same ground for three years (April 1998- December 2000). The cooperating grower will grow sudangrass in 1998 and sudangrass or any other crop after the first year for the duration of the study (according the commercial cultural practices in the Imperial Valley).

Location 1 sudangrass (fields A & B)

Field A: Standard irrigation practices in the Imperial Valley. All irrigation and cultural practices will be determined by the cooperating grower. The cooperating grower is expected to inform the project contact person of irrigation dates and hay cutting/baling dates at least 24 hours prior to each event.

Measurements:

Project staff and IID will measure the amount of applied water, surface runoff, and hay (or crop) yield. Project staff will take the necessary measurements to evaluate irrigation efficiency, water use efficiency, hay yield and quality (crude protein, acid detergent fiber, and neutral detergent fiber). The following parameters will be determined:

- Average depth of applied water
- Soil moisture content prior to and after each irrigation event
- Water table depth prior to and after each irrigation event
- Water table salinity and chloride concentration prior to and after each irrigation event
- Surface runoff water during and after irrigation events
- Soil salinity (twice a year)
- Soil chloride content (twice a year)
- Average yield after each cutting (or crop harvest)
- Hay quality (twice a year)
- Drainage water salinity and chloride content
- Estimate of drainage outflow

Field B: Reduced irrigation treatment I. Standard irrigation practices in the Imperial Valley except that runoff will be reduced from the current average of 17% of applied water to less than 5% of applied water after stand establishment. All irrigation and cultural practices will be determined by the cooperating grower **except that the project will determine and order the amount of water needed** for irrigation. The cooperating grower is expected to inform the project contact person of irrigation dates and hay cutting/baling dates at least 24 hours prior to each event.

Measurements:

Project staff and IID will measure the amount of applied water, surface runoff, and hay (or crop) yield. Project staff will take the necessary measurements to evaluate irrigation efficiency, water use efficiency, hay yield and quality (crude protein, acid detergent fiber, and neutral detergent fiber). The following parameters will be determined:

- Average depth of applied water
- Soil moisture content prior to and after each irrigation event
- Water table depth prior to and after each irrigation event
- Water table salinity and chloride concentration prior to and after each irrigation event
- Surface runoff water during and after irrigation events
- Soil salinity (twice a year)
- Soil chloride content (twice a year)
- Average yield after each cutting (or crop harvest)
- Hay quality (twice a year)

- Drainage water salinity and chloride content
- Estimate of drainage outflow

To account for soil spatial variability one set of borders in this treatment will be irrigated similarly to treatment A.

Location 2 sudangrass (fields A & B)
Field A: Same as field A in Location 1 sudangrass

Measurements:
Same as field A in Location 1 sudangrass

Field B: Same as field B in Location 1 sudangrass

Measurements:
Same as field B in Location 1 sudangrass

Difficulties with this.

3.4 All alfalfa and sudangrass locations (Fields A and B)

what about recession curves? Infiltration rates?

We will evaluate the irrigation efficiency of each field by taking advance, runoff, and flow rate measurements and total applied water and surface runoff water. Soil moisture distribution in at least two borders will be evaluated using a neutron probe or a similar device. A total of 16 9-ft neutron probe (or a similar device) access tubes will be installed in each field to characterize soil moisture distribution in the field. Moisture measurements will be taken at depths of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0, 7.0, 8.0, and 9.0 ft prior to and approximately two days following each irrigation event. Gravimetric soil moisture samples will be taken in the 0-6" depth range. Evapotranspiration estimates during and two days following irrigations will be obtained from the closest CIMIS weather station and will be added to the difference in soil moisture prior to and following each irrigation event. Soil samples will be taken twice a year from each field at various depths (0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0 ft) to evaluate soil salinity before the first cut and throughout the project. A total of 16 10-ft observation wells will be installed in each field next to access tube locations. Water samples from each well will be taken for chemical analysis of the shallow groundwater throughout the project. Regional influence may affect results.

Too soon + [illegible] problems

sites or field

Alfalfa or sudangrass yield will be determined for each cutting (bales in the field as well as small sections of alfalfa or sudangrass yield next to each access tube location). Statistical methods of evaluation will involve the use of ANOVA and time series analysis software.

Advance time will be recorded every 100 ft along the selected borders. The commonly used Kostiakov and modified Kostiakov equations

$$z=kt^a \text{ and} \quad (1)$$

$$z=kt^a+ct, \text{ respectively,} \quad (2)$$

where z is the depth of water infiltrated, t is the intake opportunity time, k and a are empirical

?

constants, and c is the steady infiltration rate, and other infiltration function will be used as needed to simulate border irrigation performance in a volume-balance model. Infiltration function parameters k and a will be obtained for each irrigation and each border from advance data using a power advance function of the form

$$\cancel{X=pt^r} \tag{3}$$

where X is the advance distance (m), t is the advance time (min), and p and r are fitted parameters. The above power advance function will be used to predict the infiltration function parameters k and a of the Kostiakov equation using the two-point method. Simulated and field-measured irrigation performance characteristics of border irrigation (application efficiency, distribution uniformity, surface runoff, deep percolation, and depth infiltrated) will be evaluated for all irrigations using spatially averaged and temporally variable infiltration characteristics.

4 Surface Runoff Reduction Method

who developed this method? need to see a write-up

Irrigation scheduling can be based on a relatively simple technique that predicts the cutoff time necessary to minimize runoff and to improve water use efficiency. While the method is applicable for all soils, it works best in heavy clay soils. The method is a combination of a volume balance model and a two-point measurement method.

The main objective in heavy clay soils is to have enough water to fill cracks with little or no runoff. The cutoff time can be calculated for a given border using a volume balance model where the total volume of water applied equals the surface storage and the subsurface storage. At any time (t_x) the volume applied, V, is

$$V=Q*t_x$$

Where Q is the inflow rate in cubic feet per second (cfs) and t_x is the time in minutes. The surface storage (SY) equals the product of the average depth of water and the area covered by water

$$SY=\sigma_y*d*w*l_x$$

where σ_y is the surface shape factor (0.6-0.8), d is the depth of water at the water inlet in feet, w is the width of border in feet, and l_x is the advance distance at time t_x.

The subsurface storage (SZ) equals the product of the average depth stored and the area covered by water. Earlier in the irrigation, soil cracks dominate the process of infiltration and the volume of the subsurface storage is essentially the volume of cracks. Thus,

Is this a mathematical analysis of a physical event (i.e the irrigation)?

$$SZ = z * w * l_x$$

where z is the average depth stored below the soil surface in feet, and w and l_x are as defined earlier. The total volume, V, is the sum of the surface storage and subsurface storage:

$$V = SY + SZ$$

The average depth stored below the surface can be found at any time, t_x.

$$Q * t_x = (\sigma_y * d * w * l_x) + (z * w * l_x)$$

$$z = \frac{(Q * t_x - \sigma_y * d * w * l_x)}{(w * l_x)}$$

when z is known, the time of cutoff, t_{co}, can be determined to minimize runoff. The total volume applied ($Q*t_{co}$) equals to the volume stored:

$$Q * t_{co} = w * L * z$$

$$t_{co} = \frac{(w * L * z)}{Q}$$

where L is the total length of the border.

The following information is needed to determine cutoff time:

1- Border length and width in feet.
2- Average flow rate in cfs.
3- Depth of the water at the inlet (or soil roughness).
4- One or two points of water advance with time along the border.

5 **BUDGET:** Two alfalfa locations (4 fields) and two sudangrass locations (4 fields)

	1997* (Nov.16 - Dec. 31)	1998	1999	2000	Total
Salaries					
(2 SRA step I: $27,468/yr per FTE, 2 Lab Asst step II: $21,660/yer per FTE)	$12,282	$98,256	$103,169	$108,327	$322,034
Benefits (28% of salary)	$3,439	$27,512	$28,887	$30,332	$90,170
Subtotal	$15,721	$125,768	$132,056	$138,659	$412,204
Equipment					
Soil augers		$500	$500		$1,000
Computer and printer		$2,500			$2,500
Salinity & Ion electrodes		$2,600			$2,600
Neutron probe/soil moisture measuring devices		$4,500			$4,500
2 County/University trucks		$13,800	$14,490	$15,215	$43,505
Subtotal		$23,900	$14,990	$15,215	$54,105
Supplies					
Irrigation & soil sampling supplies		$3,500	$2,500	$2,500	$8,500
Reagents and chemical supplies		$2,400	$2,600	$2,600	$7,600
Radiation use authorizations and training on Neutron probe		$1,400	$1,500	$1,600	$4,500
Subtotal		$7,300	$6,600	$6,700	$20,600
Travel					
To present findings and for travel to/from UCD.		$1,200	$1,300	$1,400	$3,900
Total direct cost	$15,721	$158,168	$154,946	$161,974	$490,809
Indirect cost (10% to all except equipment)	$1,572	$13,427	$13,996	$14,676	$43,671
Total	$17,293	$171,595	$168,942	$176,650	$534,480

How is this allocated between alfalfa & sudan?

9-17

Memo to File

June 19, 1997

Subject: Telephone conversation with Khaled Bali related to a request for data related to his project titled: Irrigation and Drainage Management and Surface Runoff Reduction in the Imperial Valley Project

Discussion Items

- I explained the need and desire of the IID to have access to his project data and information for use in developing on-farm programs related to the IID/San Diego water transfer. In addition, I told him that I believe as a project participant, the agreement allows IID access to all data related to the project.

- Khaled disagreed and said that he understands that only completed reports with data need be released to project participants.

- I requested copies of reports, presentations, and all data related to surface water, ground water, irrigation, and crop yields.

- Khaled explained that he believed he is caught between parties using his project to advance some agenda and in fact wished he had never gotten involved in this project.

- Therefore Khaled, "as a researcher", is not interested in giving out any information other than what is contained in completed reports and presentations. He agreed to fax me a copy of a paper he presented in England. Khaled stated that Tim O'Halloran and Eldon Moore had discussed with him what topics would be appropriate to be included in this paper.

- As I understand from other sources, Khaled also was co-author on another paper presented in England. I have a copy of this paper.

- Khaled will issue the May Progress Report soon and hopes to complete an interim report within a month.

- Based on a meeting in May with the IID, USBR and Water Resources, a date in August was set to determine if additional work was needed to be completed on this project.

Conclusion

- We agreed that IID will make a formal request of Khaled's project data to the person signing the contract for the University of California (Carol Berman) and that Khaled would provide to IID what ever the University directs him to do.

9-18

COOPERATIVE EXTENSION
UNIVERSITY OF CALIFORNIA
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TELEPHONE:
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FAX NUMBER:
(619) 352-0846

May 2, 1997

Fawzi Karajeh - DWR **Fax (916) 327-1815**
Tim O'Halloran -IID **Fax (619) 339-9262**
Steve Jones -USBR **Fax (702) 293-8042**

Re: Progress Report- Runoff Reduction Project

Attached please find a draft of our third progress report for the above project. If you have any comments or suggestions about the attached report, please forward them to me by fax (760-352-0846) or email (kmbali@ucdavis.edu) no later than May 29, 1997.

Thank you for your time and consideration.

Post-it® Fax Note 7671	Date 5/2/97 # of pages ▸ 6
To Tim O'Halloran	From K. Bali
Co./Dept.	Co.
Phone #	Phone #
Fax #	Fax #

Sincerely,

Khaled M. Bali
Associate Cooperative Extension advisor
Irrigation/Water Management

DRAFT

DRAFT

THIRD PROGRESS REPORT DUE 5/31/97

Irrigation and Drainage Management and Surface Runoff Reduction in Imperial Valley

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DRAFT **DRAFT**

Summary:

Alluvial clay soil at the University of California Desert Research and Extension Center, Holtville, CA, was cultivated and alfalfa seeds were planted in November 1995 (Field No. 2). Sudangrass was planted in April 1996 and April 1997 (Field No. 1). A total of 15 acres are used in this project. The area is divided into 2 fields each containing separate plantings of alfalfa and sudangrass. Each field contains 4 borders where each border is 65 ft*1250 ft. Thirty two sampling locations were established in teach field to evaluate soil moisture and soil salinity at 14 different depths (6 inches to 9 ft). Moisture contents at all sampling locations were determined by the neutron probe. The neutron probe was calibrated for each field. Soil moisture measurements were made prior to each irrigation and 2 or 3 days after each irrigation. Alfalfa and sudangrass hay samples were taken for yield determination. Summary of alfalfa and sudangrass yield data are presented in the progress report.

Field No. 1, Crop: Sudangrass

1996 Season: Planting rates and dates: Sudangrass (cv. 'Piper') was planted on April 15, 1996 at the rate of 120 pounds of seed per acre.

1996 season
Irrigation dates:
1-18-96 (preirrigation)
4-16-96
5-3-96
5-24-96
6-28-96
7-23-96
8-20-96
9-17-96

Sudangrass was cut on:

Cut date	Average yield (tons/acre) field wt.	Average yield (tons/acre) adjusted to 10% moisture
6-17--96	2.38	2.37
8-7-96	2.25	2.24
10-10-96	2.13	2.23
Total 1996	6.76	6.84

Soil samples between 3-29-96 and 11-25-96

DRAFT

1997 season

1997 Season: Planting rates and dates: Sudangrass (cv. 'Piper') was planted on April 18, 1997 at the rate of 120 pounds of seed per acre.

Pest control and harvesting: According to the commercial practices of sudangrass production in Imperial Valley.

Irrigation dates:
4-21-97

Field No. 2, Crop: Alfalfa

Alfalfa (CUF 101) was planted on November 7, 1995 at a rate of 30 pounds of seed per acre.

Pest control and harvesting: According to the commercial practices of alfalfa production in Imperial Valley.

Irrigation Date(s)
11-8-95
12-4 & 12-5-95
1-22 & 1-23-96
3-19-96
4-24-96
5-17-96
6-7-96
7-3-96
8-2-96
9-10-96
11-1-96
12-20-96
2-19-97
4-7-97

4-28-97

DRAFT

Soil samples between 11-3-95 and 4-7-97

Alfalfa was cut on:

Cut date	Average yield (tons/acre) field wt.	Average yield (tons/acre) adjusted to 10% moisture
3-6-96	0.96	0.88
4-17-96	0.91	0.87
5-30-96	1.49	1.40
6-24-96	1.97	1.91
7-24-96	1.08	1.08
8-28-96	0.88	0.77
10-21-96	0.58	0.57
12-11-96	0.55	0.55
Total 1996	8.42	8.03
2-4-97		
3-27-97*		
5-**-97		

* to control insect damage (aphid and weevil), field sprayed on 4/4/97

** planning on 5/9 or 5/12/97

Alfalfa yields (alfalfa yield next to each of the 32 sampling locations, sample area is 0.91 m*6.10 m) on;

Cut date	Average yield (Kg/ha) dry matter	Average yield (tons/acre) adjusted to 10% moisture
3-4-96	2768	1.34
4-17-96	2801	1.36
5-28-96	3822	1.85

DRAFT

6-24-96	3971	1.92
7-24-96	2896	1.40
8-27-96	1947	0.94
10-15-96	1845	0.89
12-9-96	1402	0.68
Total 1996	21452	10.38
2-3-97		
5-**-97		

Fields 1 and 2

Colorado River water was applied to all fields. We evaluated the irrigation efficiency of each field and for each irrigation by taking advance, recession, and flow rate measurements for all borders. Infiltration rates were evaluated for each irrigation using the advance function. A total of 32 9-ft neutron probe access tubes were installed in each field (eight neutron probe access tubes were installed in each border) to characterize soil moisture distribution in the field. Moisture measurements were taken at depths of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0, 7.0, 8.0, and 9.0 ft prior to and two or three days following each irrigation. Gravimetric soil moisture samples were taken in the 0-6" depth range because the neutron scattering technique does not accurately estimate soil moisture content near the surface. Evapotranspiration during and for the two or three days following irrigations were obtained from CIMIS weather station No. 87 and were added to the difference in soil moisture prior to and following each irrigation. A total of 32 10-ft observation wells were installed in each field. Water samples from each well were taken for salinity and Cl analysis of the shallow groundwater. Soil samples from the 32 locations in each field were taken at various depths to evaluate soil salinity.

9-19

Irrigation and Drainage Management and Surface Runoff Reduction in Imperial Valley

Principal Investigators:

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Cooperators:

Richard L. Snyder, Ph.D.
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Duration of the Project: 3 years (September 1, 1995 - December 31, 1998)

Executive Summary:

Colorado River water is the only source of irrigation and drinking water in the Imperial Valley, however it contains more salts than any other surface irrigation source in California. As much as 2.8 million acre-feet of Colorado River water are used every year to irrigate more than 500,000 acres of lands in the Imperial Valley. Surface and subsurface drainage water enters the Salton Sea which serves as a drainage sink for the Imperial and Coachella Valleys since its formation in 1905. The Salton Sea continues to exist because of the drainage water from agriculture in Imperial and Coachella Valleys as well as flow of agricultural drainage and untreated and partially treated sewage from the Mexicali Valley. Because of drainage and its impact on the Sea, several water quality issues exist in the Imperial Valley for which water conservation plays a role.

The Salton Sea water surface elevation has recently (May 1995) reached the highest level in record since 1920. The overall peak elevation for 1994 exceeds that of 1992 by approximately 0.7-0.8 ft. Surface runoff and subsurface drainage water from agricultural lands in Imperial Valley contribute to this increase in elevation. Currently, the salinity of the Sea is nearly 46,000 ppm or approximately 130% the salinity of the Pacific Ocean. Our objective is to conduct a research and demonstration project that will improve irrigation efficiency, reduce surface runoff, utilize the shallow saline water table for new and improved irrigation and drainage management practices, determine crop coefficients for two common field crops (alfalfa and sudangrass) and increase utilization of CIMIS for irrigation scheduling. We are also planing to publish a Handbook about the best management practices for reducing surface and subsurface drainage water. All educational activities will be conducted in cooperation with the Imperial Irrigation District (IID) and the California Department of Water Resources (DWR).

More than 15% of the delivered irrigation water in Imperial Valley becomes tailwater runoff. This water transports significant amounts of chemicals that eventually reach the Salton Sea. Efficient irrigation practices are needed to minimize runoff and to reduce the amount of chemicals in runoff water. This study will focus on development and demonstration of a new method to predict irrigation cutoff time from pre-determined soil moisture status of the clay soil of interest. Issues related to salinity, irrigation management, and water quality will also be addressed in this project. Since soil salinity and water management are affected by water table depth, a major part of this study will be to quantify the effect of water table control on soil salinity, water infiltration rates, and irrigation efficiency. To observe cumulative aspects of reduced water table depth on soil salinity and consumptive water use, this study will be conducted for three years.

Our work will focus on field crops, specifically alfalfa and sudangrass. Field crops account for almost 80% of the 500,000 acres of irrigated land in the Imperial Valley and alfalfa and sudangrass rank 2nd and 7th, respectively, in terms of total production (1993 Imperial County Agricultural Crop and Livestock report). These two major field crops were grown on more than 236,000 acres of irrigated lands in Imperial Valley in 1993.

Educational Elements:

A user-friendly computer program considering practical applications of the BMP's described in Handbook will be developed by the principle investigators. The program will include educational elements about water quality as well as practical applications of surface runoff reduction methods that will be developed as part of this research project at the University of California Desert Research and Extension Center.

Other educational forums of this project include:

1. Irrigation Management and Surface Runoff Conference.
2. Field Days (three).
3. UC Publication Best Management Practices Handbook, "BMPs for Irrigation Management and Surface Runoff Reduction in Clay soils".
4. Computer program and worksheets to improve irrigation efficiency in clay soils

A comprehensive guide to irrigation and drainage management and BMPs for runoff reduction in the Imperial Valley will be developed by the principal investigators with contributions from other scientists. This Guide will be completed by December 31 1998 and will be available to growers and the general public. Several field days and seminars will be conducted during the project. Field days, seminars and shortcourses will be conducted by the principal investigators and invited speakers from University of California, Department of Water Resources , Imperial Irrigation District, and farmers. Findings from this research and demonstration project will be published in local, statewide, and national agricultural magazines such as California Agriculture, CA/AZ Farm Press, California Farm Bureau's Ag. Alert, and scientific journals.

Introduction:

Temporal (during the season) variability of infiltration is often the cause of excessive runoff and poor irrigation efficiency in heavy clay soils. The ability to predict changes in infiltration characteristics is the key to improve application efficiency (AE) and distribution uniformity (DU) of surface irrigation systems (Jensen, 1980). Simulation models of surface irrigation systems often use the same infiltration function throughout the season. The ability to predict surface irrigation system performance is directly influenced by temporal and spatial soil variability.

Several investigators have considered different aspects of infiltration variability in irrigated fields. Izadi and Wallender (1985) quantified the effect of soil variability on infiltration characteristics. Linderman and Stegman (1971) showed that infiltration characteristics varied during the season. Vieira et al. (1981) studied the spatial variability of field-measured infiltration rates. Wallender (1986) developed a volume balance furrow irrigation model with spatially varying infiltration characteristics and Bali and Wallender (1987) studied the combined effect of soil variability and intake opportunity time on furrow irrigation systems performance. They also studied field-measured and simulated furrow irrigation system performance under spatially and temporally varied infiltration function parameters. Cracking of soils was most likely the source of variability between simulated and observed field advance rates. Bali et al. (1994)

showed that spatial variability of infiltration in heavy clay soils did not have significant impacts on surface irrigation system performance as compared to temporal variability. Grismer and Tod (1994) tested a field procedure to estimate irrigation time in cracking clay soils using a volume balance method.

Heavy clay soils represents more than 60% of the nearly 200,000 ha of irrigated land in the Imperial Valley, CA. Approximately 16% of the irrigation water is lost to surface runoff due to the limited infiltration in clay soils. Water penetration is usually limited to free water flow into cracks and infiltration parameters vary widely between irrigations over the season. This research will be conducted to study the effect of changes in water table elevation on surface irrigation system performance and surface runoff in a cracking clay soil. The specific objectives of this research and demonstration project are:

1- Determine the best management practices (BMPs) for surface runoff reduction in heavy clay soils of the Imperial Valley.
2- Determine the effect of water table control on irrigation management and consumptive use of water by alfalfa and sudangrass (including crop coefficients for alfalfa and sudangrass).
3- Determine the contribution of shallow saline water tables to crop evapotranspiration in heavy clay soils.
4- Develop a relatively simple approach to predict irrigation cutoff time from pre-determined soil moisture measurements.
5- Develop a user-friendly computer program and irrigation management spreadsheets for efficient irrigation management practices. These tools include: the use of CIMIS for irrigation scheduling, prediction of crop water requirements for alfalfa and sudangrass, and prediction of seasonal changes in AE, DU, and surface runoff.
6- Conduct field days, demonstrations, seminars, and publish results in both popular and scientific media.

This research and demonstration project will be conducted at the University of California Desert Research and Extension Center (UCDREC) near Holtville, CA, a site having soils that are typical of the major acreage of Imperial Valley Soils.

Procedures

A total of 15 acres will be used in this research project. The area will be divided into 2 fields each containing separate plantings of alfalfa and sudangrass. Each field will be further divided into 4 borders where each border is 65 ft*1250 ft.

Field No. 1, Crop: Sudangrass

Sudangrass growing seasons (March-October, 1996, 1997, and 1998)

Planting rates and dates: Sudangrass (cv. 'Piper') will be planted in March 1996, March 1997, and March 1998 at a rate of 120 pounds of seed per acre.

Pest control and harvesting: According to the commercial practices of sudangrass production in Imperial Valley.

Water table control: The water table will be lowered to at least 15 ft below land surface in the upper 500 ft of the middle two borders as compared to a normal water table depth of 4-5 ft below land surface in the proposed field.

Field No. 2, Crop: Alfalfa

Alfalfa growing season (October 1995 - October 1998)

Planting rates and dates: Alfalfa (CUF 101) will be planted in October 1995 at a rate of 30 pounds of seed per acre.
Pest control and harvesting: According to the commercial practices of alfalfa production in Imperial Valley.

Water table control: Tile drains will be blocked in the upper 500 ft of all borders in this field so as to encourage maximum crop use of the shallow water table. Preliminary studies indicate that the water table rises to within 3-4 ft of the land surface in blocked drain fields.

Fields 1 and 2

Colorado River water will be applied to all fields. We will evaluate the irrigation efficiency of each field by taking advance, recession, runoff and flow rate measurements for all borders. Initial infiltration rates will be measured during each irrigation as described by Bali and Wallender (1987) and soil samples will be collected at various depths after each irrigation. The samples will be analyzed for Na, Ca, Mg, K, Cl, and trace elements such as Se and B. Soil moisture distribution in each border will be evaluated using the neutron probe. A total of 32 9-ft neutron probe access tubes will be installed in each field (eight neutron probe access tubes will be installed in each border) to characterize soil moisture distribution in the field. Moisture measurements will be taken at depths of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0, 7.0, 8.0, and 9.0 ft prior to and two days following each irrigation. Gravimetric soil moisture samples will be taken in the 0-15 cm depth range because the neutron scattering technique does not accurately estimate soil moisture content near the surface. Evapotranspiration estimates during and two days following irrigations will be obtained from a nearby CIMIS weather station (station no. 87) and will be added to the difference in soil moisture prior to and following each irrigation. Soil samples will be regularly taken at various depths to evaluate soil salinity. A total of 32 10-ft observation wells will be installed in each field. Water samples from each well will be taken for chemical analysis of the shallow groundwater throughout the project.

Irrigation scheduling will be based on CIMIS data and on soil moisture measurements as described by Snyder and Bali (1992). Surface runoff and drainage water samples will be taken for chemical analysis. The samples will be analyzed for Na, Mg, Ca, K, Cl, EC, and TDS.

Alfalfa and sudangrass yield will be determined for each cutting and standard statistical analyses will be used to evaluate the effectiveness of different water table elevations. Statistical methods of evaluation will involve the use of ANOVA and time series analysis software.

All irrigations will be started from the south end of the field and advance time will be recorded every 50 ft along each border. The commonly used Kostiakov and modified Kostiakov equations

$$z=kt^a \text{ and} \tag{1}$$

$$z=kt^a+ct, \text{ respectively,} \tag{2}$$

where z is the depth of water infiltrated, t is the intake opportunity time, k and a are empirical constants, and c is the steady infiltration rate, will be used to simulate border irrigation performance in a volume-balance model (Elliott and Walker, 1982). Infiltration function parameters k and a will be obtained for each irrigation and each border from advance data using a power advance function of the form (Walker and Skogerboe, 1987)

$$X=pt^r \tag{3}$$

where X is the advance distance (m), t is the advance time (min), and p and r are fitted parameters. The above power advance function will be used to predict the infiltration function parameters k and a of the Kostiakov equation using the two-point method (Elliott and Walker, 1982). Simulated and field-measured irrigation performance characteristics of border irrigation (AE, DU, surface runoff, deep percolation, and depth infiltrated) will be evaluated for all irrigations using spatially averaged and temporally variable infiltration characteristics.

Advance rates from all irrigations over the season will be correlated with soil moisture content before the corresponding irrigation and actual volume of applied water. An empirical function describing the relationship between moisture content before irrigation and advance rate and cutoff time will be developed for various flow rates and soil moisture depletion levels (see appendix A for details).

The empirical function for eliminating surface runoff will be tested for soil moisture depletion levels between 2.5 and 6 inches over the entire root zone. Statistical methods of evaluation will involve the use of the time series analysis procedures (Davis, 1973).

Summary of work plans:

* sudangrass planted for three successive years on the same ground (Field No. 1)
* Sudangrass planted in March and harvested until October
* alfalfa planted in October 1995 (duration of crop: 3 years, Field No. 2)
* water table lowered from 5 to 15 ft in the upper 500 ft of field No. 1 (sudangrass)
* tile drains blocked in the upper 500 ft of field No. 2 (alfalfa)
* hay yield at each cutting (weighing bales in field)
* infiltration rates and irrigation performance characteristics will be evaluated for each treatment throughout the experiment
* soil samples for chemical analysis will be collected throughout the experiment.
* drainage flow rate will be monitored
* surface runoff will be evaluated and water samples will be collected on a regular basis.

* water table elevation and salinity will be monitored on a regular basis (32 observation wells in each field)
* consumptive water use is determined between irrigations
* ANOVA and time series analysis methods used to determine statistical parameters of concern in the experiments.

Proposed Budget:

	1995-96	1996-97	1997-98	Total
Staff research assistant	$26,700	$27,600	$28,600	
Field Assistants/helpers	$3,600	$3,900	$4,300	
Seed, fertilizer, pesticide, sprinkler, etc. (alfalfa and sudangrass)	$4,500	$2,400	$2,400	
Irrigation and soil sampling supplies	$500	$500	$500	
Pump for drainage water removal and plumbing supplies	$4,000	$400	$400	
Permanent Equipment auger, computer, printer software, and computer supplies for data collections and field days	$3,500	$600	$600	
Field days, short courses expenses and BMP publication cost	$700	$700	$1500	
Reagents and chemical supplies/analysis	$600	$600	$600	
Radiation use authorizations and training on Neutron probe	$350	$400	$400	
Travel To present findings and for travel to/from UCD.	$1,200	$1,200	$1,900	
Subtotal	$45,650	$38,300	$41,200	$124,150
Indirect cost (10%)	$4,565	$3,830	$4,120	$12,415
Total	$50,215	$42,130	$45,320	$137,665

Inkind support:

		1995-96	1996-97	1997-98	1998-99
Total					
University of California					
Personnel and time commitment					
Bali	20%	$10,700	$10,700	$10,700	
Grismer	10%	$8,300	$8,300	$8,300	
SRA (M. Jimenez)	50%	$20,337	$20,337	$20,337	
UCDREC (land & labor)		$11,250	$11,250	$11,250	
Imperial County					
County Funds		$5,592	$5,592	$5,592	
Total inkind support		$56,179	$56,179	$56,179	157,287

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APPENDIX A:

Irrigation scheduling can be based on a relatively simple technique that predicts the cutoff time necessary to minimize runoff and to improve water use efficiency. While the method is applicable for all soils it works best in heavy clay soils. The method is a combination of a volume balance model and a two-point measurement method.

The main objective in heavy clay soils is to have enough water to fill cracks with little or no runoff. The cutoff time can be calculated for a given border using a volume balance model where the total volume of water applied equals the surface storage and the subsurface storage. At any time (t_x) the volume applied, V, is

$$V=Q*t_x$$

Where Q is the inflow rate in cubic feet per second (cfs) and t_x is the time in minutes. The surface storage (SY) equals the product of the average depth of water and the area covered by water

$$SY=\sigma_y*d*w*l_x$$

where σ_y is the surface shape factor (0.6-0.8), d is the depth of water at the water inlet in feet, w is the width of border in feet, and l_x is the advance distance at time t_x.

The subsurface storage (SZ) equals the product of the average depth stored and the area covered by water. Earlier in the irrigation, soil cracks dominate the process of infiltration and the volume of the subsurface storage is essentially the volume of cracks. Thus,

$$SZ=z*w*l_x$$

where z is the average depth stored below the soil surface in feet, and w and l_x are as defined earlier. The total volume, V, is the sum of the surface storage and subsurface storage:

$$V=SY+SZ$$

The average depth stored below the surface can be found at any time, t_x,

$$Q*t_x=(\sigma_y*d*w*l_x)+(z*w*l_x)$$

$$z=\frac{(Q*t_x-\sigma_y*d*w*l_x)}{(w*l_x)}$$

when z is known, the time of cutoff, t_{co}, can be determined to minimize runoff. The total volume applied ($Q*t_{co}$) equals to the volume stored:

$$Q*t_{co}=w*L*z$$

$$t_{co}=\frac{(w*L*z)}{Q}$$

where L is the total length of the border.

The following information is needed to determine cutoff time:

1- Border length and width in feet.
2- Average flow rate in cfs.
3- Depth of the water at the inlet (or soil roughness).
4- One or two points of water advance with time along the border.

Proposed Approach to determine cutoff time:

Our objective is to predict the average depth of infiltration, z, from soil moisture depletion using

$$D=(\theta_{max}-\theta)R$$

where D is soil moisture depletion in feet, $theta_{max}$ is volumetric soil moisture content at saturation, theta is the average volumetric soil moisture content of the root zone before the irrigation event, and R is root zone depth in feet.

Our results have shown that z is directly related to D and R, or in other words z=f(D,R). However, at this time, we will assume that z is a function of D only (z=f(D)). We will evaluate this empirical function from measured values of D and z at several soil moisture depletion levels. Once the function is determined, the cutoff time (t_{co}) can be determined in advance using the following equation

$$t_{co}=\frac{w*L*f(D)}{Q}$$

This equation allows us to predict the time of cutoff before the irrigation event. The advance function can also be predicted. The advance function can be described by

$$x=pt^{r}$$

where t is the time since the start of advance and p and r are fitted parameters ($r \approx 1$ for near linear advance, $r=1$ for linear advance). The average depth stored below the soil surface, z, can be calculated from

$$z=\frac{Q*t_{co}}{W*L}$$

For a linear advance ($x=pt$), the slope of advance, p equals l_x/t_x and when t_x equals t_{co}, l_x is the distance of advance at the time of cutoff, and therefore p can be evaluated from

$$p=\frac{Q}{(\sigma_y*d*W)+(f(D)*W)}$$

Predicted and measured values of p will be compared. The above approach is valid when the soil's bulk density is constant over a wide range of moisture content. However, in clay soils, bulk density is directly affected by moisture content. We will account for this fact by using a bulk density function which is dependent on moisture content.

9-20

COOPERATIVE EXTENSION
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July 3, 1995

Tim F. O'Halloran
Supervisor, Irrigation Management Unit
Imperial Irrigation District
P. O. Box 937, Imperial, CA 92251
Fax: (619) 355-1268

Re: Irrigation and Drainage Management and Surface Runoff Reduction in Imperial Valley

Dear Tim:

Thank you for taking the time to meet with me on June 15, 1995 and for your fax of June 29, 95. Mark Grismer and I reviewed your comments about the executive summary, and revised it to consider your suggestions. Attached is a revised draft of our proposal. In addition, we modified objective 2 to explicitly include crop coefficients for alfalfa and sudangrass.

While we realize that there are many different perspectives on what should be done in this subject area, we think that we have common objectives to serve the water users and improve irrigation and drainage management and increase the utilization of CIMIS for irrigation scheduling. While the focus of this work is in Imperial Valley, we believe that this project will help growers in our area as well as growers in the West San Joaquin Valley who have similar soils and crops.

This proposal has88888 already been reviewed by the UC Desert Research and Extension Center Research Advisory Committ8ee (RAC). Our request for land and labor to conduct the project at the Center has been approved by the RAC. However, if you feel that some of the work should be done on commercial fields, we would seek your assistance in identifying growers willing to participate in this project. We welcome the addition of extra objectives to this project that you or the IID may think valuable to the Imperial Valley.

I hope you agree with our overall objectives of this project and will be willing to participate as a cooperator. I am looking forward to your decision on this request, and would greatly appreciate your response as soon as possible or at most by July 17, 1995. Once again thank you for your help and consideration.

Sincerely,

Khaled M. Bali
Farm Advisor
Irrigation/Water Management

Enc. Revised proposal

c: R. Gonzalez
M. Grismer
J. Silva

REVISED DRAFT

Irrigation and Drainage Management and Surface Runoff Reduction in Imperial Valley

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Tim F. O'Halloran
Supervisor, Irrigation Management Unit
Imperial Irrigation District
P. O. Box 937, Imperial, CA 92251
(619) 339-9081 Fax: (619) 355-1268

Duration of the Project: 3 years (August 1, 1995 - December 31, 1998)

Executive Summary:

Colorado River water is the only source of irrigation and drinking water in the Imperial Valley, however it contains more salts than any other surface irrigation source in California. As much as 2.8 million acre-feet of Colorado River water are used every year to irrigate more than 500,000 acres of lands in the Imperial Valley. Surface and subsurface drainage water enters the Salton Sea which serves as a drainage sink for the Imperial and Coachella Valleys since its formation in 1905. The Salton Sea continues to exist because of the drainage water from agriculture in Imperial and Coachella Valleys as well as flow of agricultural drainage and untreated and partially treated sewage from the Mexicali Valley. Because of drainage and its impact on the Sea, several water quality issues exist in the Imperial Valley for which water conservation plays a role.

The Salton Sea water surface elevation has recently (May 1995) reached the highest level in record since 1920. The overall peak elevation for 1994 exceeds that of 1992 by approximately 0.7-0.8 ft. Surface runoff and subsurface drainage water from agricultural lands in Imperial Valley contribute to this increase in elevation. Currently, the salinity of the Sea is nearly 46,000 ppm or approximately 130% the salinity of the Pacific Ocean. Our objective is to conduct a research and demonstration project that will improve irrigation efficiency, reduce surface runoff, utilize the shallow saline water table for new and improved irrigation and drainage management practices, determine crop coefficients for two common field crops (alfalfa and sudangrass) and increase utilization of CIMIS for irrigation scheduling. We are also planing to publish a Handbook about the best management practices for reducing surface and subsurface drainage water. All educational activities will be conducted in cooperation with the Imperial Irrigation District (IID) and the California Department of Water Resources (DWR).

More than 15% of the delivered irrigation water in Imperial Valley becomes tailwater runoff. This water transports significant amounts of chemicals that eventually reach the Salton Sea. Efficient irrigation practices are needed to minimize runoff and to reduce the amount of chemicals in runoff water. This study will focus on development and demonstration of a new method to predict irrigation cutoff time from pre-determined soil moisture status of the clay soil of interest. Issues related to salinity, irrigation management, and water quality will also be addressed in this project. Since soil salinity and water management are affected by water table depth, a major part of this study will be to quantify the effect of water table control on soil salinity, water infiltration rates, and irrigation efficiency. To observe cumulative aspects of reduced water table depth on soil salinity and consumptive water use, this study will be conducted for three years.

Our work will focus on field crops, specifically alfalfa and sudangrass. Field crops account for almost 80% of the 500,000 acres of irrigated land in the Imperial Valley and alfalfa and sudangrass rank 2nd and 7th, respectively, in terms of total production (1993 Imperial County Agricultural Crop and Livestock report). These two major field crops were grown on more than 236,000 acres of irrigated lands in Imperial Valley in 1993.

Educational Elements:

A user-friendly computer program considering practical applications of the BMP's described in Handbook will be developed by the principle investigators. The program will include educational elements about water quality as well as practical applications of surface runoff reduction methods that will be developed as part of this research project at the University of California Desert Research and Extension Center.

Other educational forums of this project include:

1. Irrigation Management and Surface Runoff Conference.
2. Field Days (three).
3. UC Publication Best Management Practices Handbook,
   "BMPs for Irrigation Management and Surface Runoff Reduction in Clay soils".
4. Computer program and worksheets to improve irrigation efficiency in clay soils

A comprehensive guide to irrigation and drainage management and BMPs for runoff reduction in the Imperial Valley will be developed by the principal investigators with contributions from other scientists. This Guide will be completed by December 31 1998 and will be available to growers and the general public. Several field days and seminars will be conducted during the project. Field days, seminars and shortcourses will be conducted by the principal investigators and invited speakers from University of California, Department of Water Resources , Imperial Irrigation District, and farmers. Findings from this research and demonstration project will be published in local, statewide, and national agricultural magazines such as California Agriculture, CA/AZ Farm Press, California Farm Bureau's Ag. Alert, and scientific journals.

Introduction:

Temporal (during the season) variability of infiltration is often the cause of excessive runoff and poor irrigation efficiency in heavy clay soils. The ability to predict changes in infiltration characteristics is the key to improve application efficiency (AE) and distribution uniformity (DU) of surface irrigation systems (Jensen, 1980). Simulation models of surface irrigation systems often use the same infiltration function throughout the season. The ability to predict surface irrigation system performance is directly influenced by temporal and spatial soil variability.

Several investigators have considered different aspects of infiltration variability in irrigated fields. Izadi and Wallender (1985) quantified the effect of soil variability on infiltration characteristics. Linderman and Stegman (1971) showed that infiltration characteristics varied during the season. Vieira et al. (1981) studied the spatial variability of field-measured infiltration rates. Wallender (1986) developed a volume balance furrow irrigation model with spatially varying infiltration characteristics and Bali and Wallender (1987) studied the combined effect of soil variability and intake opportunity time on furrow irrigation systems performance. They also studied field-measured and simulated furrow irrigation system performance under spatially and temporally varied infiltration function parameters. Cracking of soils was most likely the source of variability between simulated and observed field advance rates. Bali et al. (1994)

showed that spatial variability of infiltration in heavy clay soils did not have significant impacts on surface irrigation system performance as compared to temporal variability. Grismer and Tod (1994) tested a field procedure to estimate irrigation time in cracking clay soils using a volume balance method.

Heavy clay soils represents more than 60% of the nearly 200,000 ha of irrigated land in the Imperial Valley, CA. Approximately 16% of the irrigation water is lost to surface runoff due to the limited infiltration in clay soils. Water penetration is usually limited to free water flow into cracks and infiltration parameters vary widely between irrigations over the season. This research will be conducted to study the effect of changes in water table elevation on surface irrigation system performance and surface runoff in a cracking clay soil. The specific objectives of this research and demonstration project are:

1- Determine the best management practices (BMPs) for surface runoff reduction in heavy clay soils of the Imperial Valley.
2- Determine the effect of water table control on irrigation management and consumptive use of water by alfalfa and sudangrass (including crop coefficients for alfalfa and sudangrass).
3- Determine the contribution of shallow saline water tables to crop evapotranspiration in heavy clay soils.
4- Develop a relatively simple approach to predict irrigation cutoff time from pre-determined soil moisture measurements.
5- Develop a user-friendly computer program and irrigation management spreadsheets for efficient irrigation management practices. These tools include: the use of CIMIS for irrigation scheduling, prediction of crop water requirements for alfalfa and sudangrass, and prediction of seasonal changes in AE, DU, and surface runoff.
6- Conduct field days, demonstrations, seminars, and publish results in both popular and scientific media.

This research and demonstration project will be conducted at the University of California Desert Research and Extension Center (UCDREC) near Holtville, CA, a site having soils that are typical of the major acreage of Imperial Valley Soils.

Procedures

A total of 15 acres will be used in this research project. The area will be divided into 2 fields each containing separate plantings of alfalfa and sudangrass. Each field will be further divided into 4 borders where each border is 65 ft*1250 ft.

Field No. 1, Crop: Sudangrass

Sudangrass growing seasons (March-October, 1996, 1997, and 1998)

Planting rates and dates: Sudangrass (cv. 'Piper') will be planted in March 1996, March 1997, and March 1998 at a rate of 120 pounds of seed per acre.

Pest control and harvesting: According to the commercial practices of sudangrass production in Imperial Valley.

Water table control: The water table will be lowered to at least 15 ft below land surface in the upper 500 ft of the middle two borders as compared to a normal water table depth of 4-5 ft below land surface in the proposed field.

Field No. 2, Crop: Alfalfa

Alfalfa growing season (October 1995 - October 1998)

Planting rates and dates: Alfalfa (CUF 101) will be planted in October 1995 at a rate of 30 pounds of seed per acre.
Pest control and harvesting: According to the commercial practices of alfalfa production in Imperial Valley.

Water table control: Tile drains will be blocked in the upper 500 ft of all borders in this field so as to encourage maximum crop use of the shallow water table. Preliminary studies indicate that the water table rises to within 3-4 ft of the land surface in blocked drain fields.

Fields 1 and 2

Colorado River water will be applied to all fields. We will evaluate the irrigation efficiency of each field by taking advance, recession, runoff and flow rate measurements for all borders. Initial infiltration rates will be measured during each irrigation as described by Bali and Wallender (1987) and soil samples will be collected at various depths after each irrigation. The samples will be analyzed for Na, Ca, Mg, K, Cl, and trace elements such as Se and B. Soil moisture distribution in each border will be evaluated using the neutron probe. A total of 32 9-ft neutron probe access tubes will be installed in each field (eight neutron probe access tubes will be installed in each border) to characterize soil moisture distribution in the field. Moisture measurements will be taken at depths of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0, 7.0, 8.0, and 9.0 ft prior to and two days following each irrigation. Gravimetric soil moisture samples will be taken in the 0-15 cm depth range because the neutron scattering technique does not accurately estimate soil moisture content near the surface. Evapotranspiration estimates during and two days following irrigations will be obtained from a nearby CIMIS weather station (station no. 87) and will be added to the difference in soil moisture prior to and following each irrigation. Soil samples will be regularly taken at various depths to evaluate soil salinity. A total of 32 10-ft observation wells will be installed in each field. Water samples from each well will be taken for chemical analysis of the shallow groundwater throughout the project.

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$$z=kt^a \text{ and} \tag{1}$$

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where z is the depth of water infiltrated, t is the intake opportunity time, k and a are empirical constants, and c is the steady infiltration rate, will be used to simulate border irrigation performance in a volume-balance model (Elliott and Walker, 1982). Infiltration function parameters k and a will be obtained for each irrigation and each border from advance data using a power advance function of the form (Walker and Skogerboe, 1987)

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The empirical function for eliminating surface runoff will be tested for soil moisture depletion levels between 2.5 and 6 inches over the entire root zone. Statistical methods of evaluation will involve the use of the time series analysis procedures (Davis, 1973).

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* sudangrass planted for three successive years on the same ground (Field No. 1)
* Sudangrass planted in March and harvested until October
* alfalfa planted in October 1995 (duration of crop: 3 years, Field No. 2)
* water table lowered from 5 to 15 ft in the upper 500 ft of field No. 1 (sudangrass)
* tile drains blocked in the upper 500 ft of field No. 2 (alfalfa)
* hay yield at each cutting (weighing bales in field)
* infiltration rates and irrigation performance characteristics will be evaluated for each treatment throughout the experiment
* soil samples for chemical analysis will be collected throughout the experiment.
* drainage flow rate will be monitored
* surface runoff will be evaluated and water samples will be collected on a regular basis.

* water table elevation and salinity will be monitored on a regular basis (32 observation wells in each field)
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APPENDIX A:

Irrigation scheduling can be based on a relatively simple technique that predicts the cutoff time necessary to minimize runoff and to improve water use efficiency. While the method is applicable for all soils it works best in heavy clay soils. The method is a combination of a volume balance model and a two-point measurement method.

The main objective in heavy clay soils is to have enough water to fill cracks with little or no runoff. The cutoff time can be calculated for a given border using a volume balance model where the total volume of water applied equals the surface storage and the subsurface storage. At any time (t_x) the volume applied, V, is

$$V = Q * t_x$$

Where Q is the inflow rate in cubic feet per second (cfs) and t_x is the time in minutes. The surface storage (SY) equals the product of the average depth of water and the area covered by water

$$SY = \sigma_y * d * w * l_x$$

where σ_y is the surface shape factor (0.6-0.8), d is the depth of water at the water inlet in feet, w is the width of border in feet, and l_x is the advance distance at time t_x.

The subsurface storage (SZ) equals the product of the average depth stored and the area covered by water. Earlier in the irrigation, soil cracks dominate the process of infiltration and the volume of the subsurface storage is essentially the volume of cracks. Thus,

$$SZ = z * w * l_x$$

where z is the average depth stored below the soil surface in feet, and w and l_x are as defined earlier. The total volume, V, is the sum of the surface storage and subsurface storage:

$$V = SY + SZ$$

The average depth stored below the surface can be found at any time, t_x,

$$Q*t_x=(\sigma_y*d*w*l_x)+(z*w*l_x)$$

$$z=\frac{(Q*t_x-\sigma_y*d*w*l_x)}{(w*l_x)}$$

when z is known, the time of cutoff, t_{co}, can be determined to minimize runoff. The total volume applied ($Q*t_{co}$) equals to the volume stored:

$$Q*t_{co}=w*L*z$$

$$t_{co}=\frac{(w*L*z)}{Q}$$

where L is the total length of the border.

The following information is needed to determine cutoff time:

1- Border length and width in feet.
2- Average flow rate in cfs.
3- Depth of the water at the inlet (or soil roughness).
4- One or two points of water advance with time along the border.

Proposed Approach to determine cutoff time:

Our objective is to predict the average depth of infiltration, z, from soil moisture depletion using

$$D=(\theta_{max}-\theta)R$$

where D is soil moisture depletion in feet, $theta_{max}$ is volumetric soil moisture content at saturation, theta is the average volumetric soil moisture content of the root zone before the irrigation event, and R is root zone depth in feet.

Our results have shown that z is directly related to D and R, or in other words z=f(D,R). However, at this time, we will assume that z is a function of D only (z=f(D)). We will evaluate this empirical function from measured values of D and z at several soil moisture depletion levels. Once the function is determined, the cutoff time (t_{co}) can be determined in advance using the following equation

$$t_{co} = \frac{w*L*f(D)}{Q}$$

This equation allows us to predict the time of cutoff before the irrigation event. The advance function can also be predicted. The advance function can be described by

$$x = pt^{r}$$

where t is the time since the start of advance and p and r are fitted parameters ($r \approx 1$ for near linear advance, $r=1$ for linear advance). The average depth stored below the soil surface, z, can be calculated from

$$z = \frac{Q*t_{co}}{W*L}$$

For a linear advance ($x=pt$), the slope of advance, p equals l_x/t_x and when t_x equals t_{co}, l_x is the distance of advance at the time of cutoff, and therefore p can be evaluated from

$$p = \frac{Q}{(\sigma_y*d*W)+(f(D)*W)}$$

Predicted and measured values of p will be compared. The above approach is valid when the soil's bulk density is constant over a wide range of moisture content. However, in clay soils, bulk density is directly affected by moisture content. We will account for this fact by using a bulk density function which is dependent on moisture content.